Radiological Health Data and Reports

VOLUME 10, NUMBER 7

JULY 1969

(Pages 281–328)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'co
10^{-15}	femto	f	fĕm'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^3	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 10, Number 7, July 1969

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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Published under the direction of

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Bureau of Radiological Health

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Public Health Service
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Reports

Studies of Chemical and Radiochemical Composition of Natural Gas from the Cavity Produced by the Project Gasbuggy Nuclear Shot[1]

Charles F. Smith and *Floyd F. Momyer*[2]

Data relating to the chemical and radiochemical results from Project Gasbuggy chimney-gas samples obtained prior to 210 days after detonation (December 10, 1967) are presented for significant non-radioactive components of the gas and for tritium and krypton-85. A discussion of changes in composition occurring during the flaring of 5×10^7 ft³ gas in the late spring of 1968 is included. Some interpretation of the observed changes is advanced but with the data now available, no definitive conclusions seem warranted. This is a status report of the continuing effort to define and understand the chemical and radiochemical aspects of project Gasbuggy.

Major constituents of the Gasbuggy gas during the period from 34 days to 200 days following the detonation were methane (increasing from 37 to 44 percent), ethane (increasing from 4 to 5 percent), propane (constant at ~1 percent), carbon dioxide (constant at ~36 percent), hydrogen (decreasing from 17 to 12 percent) and carbon monoxide (decreasing from 4 to less than 2 percent). Much more significant changes were observed during the first month. The major reactions used to explain these trends are:

$$CO + H_2O \rightarrow CO_2 + H_2 \quad \text{and} \quad 4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

Krypton-85 concentration (2.8 μCi/ft³) NTP (normal temperature and pressure) remained essentially constant over the entire sampling period implying mixing with a constant volume (1.2×10^8 ft³ NTP) of noncondensable gas during this time.

Tritium was observed primarily as hydrogen gas soon after detonations. A rapid decrease in HT came within the first month converting most of the HT to HTO but producing some CH_3T and C_2H_5T. The predominant tritium-containing species, except at very early time, is CH_3T, at a concentration of 12 to 14 μCi/ft³ NTP. Both CH_3T and C_2H_5T concentrations increase slightly over the first 200 days, that of HT continues to decrease. The ratios $\frac{CH_3T}{CH_4}$ and $\frac{C_2H_5T}{C_2H_6}$ are essentially constant over the period from 30 to 200 days implying that the exchange equilibrium was attained rapidly. The ratio HT/H_2 continues to decrease over the same period implying a continuing influx of non-tritiated water into the chimney and a reasonably rapid exchange reaction between HT and H_2O.

Changes in concentrations of cavity gas components as a function of flow rate indicate that removal of 30 percent of the original chimney gas was accomplished by flaring 5×10^7 ft³ at a rate of 5×10^6 ft³/day. This result is encouraging but the test was too short to provide verification of this process as a reasonable method of reducing contamination levels.

Among the more important problems related to the application of nuclear explosives to stimulation of natural gas fields is that of radioactive contamination of the gas in the chimney formed by the detonation. One of the primary objectives of Project Gasbuggy is to determine the gas quality with regard to contamination by radioactivity and to evaluate various techniques suggested for reducing this contamination.

A large quantity of data has been collected from analysis of the Gasbuggy chimney gas, and some systematic trends have been observed. Although some of the chemical and radiochemical analyses are not yet complete, that portion relating to the most important nuclides, tritium and krypton-85, can be presented, along with the mass spectrometric analyses for the major components of the gas.

[1] Work performed under the auspices of the U.S. Atomic Energy Commission. This paper was presented at the Society of Petroleum Engineers Meeting in Houston, Tex. on September 30, 1968.

[2] Dr. Smith and Dr. Momyer are associated with the Lawrence Radiation Laboratory, University of California, Livermore, Calif.

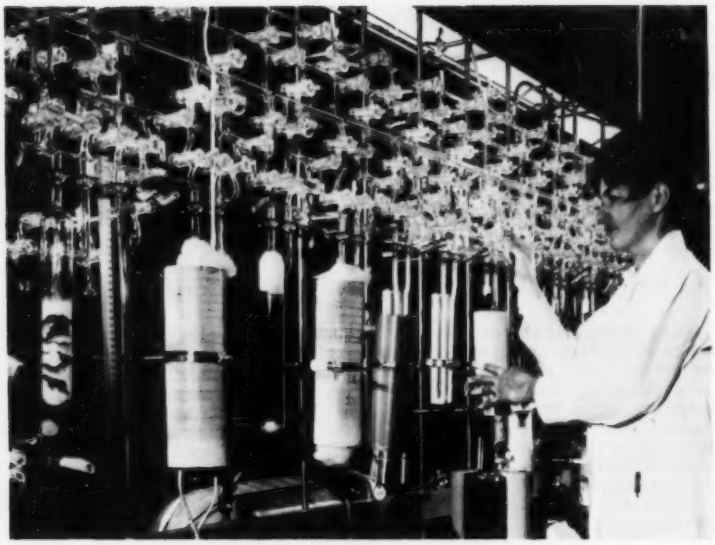

Figure 1. Chromatographic gas columns in the Radiochemistry Laboratory at the Lawrence Radiation Laboratory

Only a tentative assessment of the incomplete results is intended by this presentation. More information must be assembled before detailed interpretations of the chemistry can be made. Indeed, the lack of samples at early times when major changes were occurring may cause ambiguous interpretation of the processes involved as far as this particular experiment is concerned.

Analytical procedures

It might be of some interest to describe briefly the process by which the data are obtained. The sample is introduced to the separation system and condensed on a large activated charcoal column (figure 1). These separation systems are, in reality, large-scale gas chromatographs. Samples of Gasbuggy gas as large as ½ ft^3 can be easily separated, however, the typical sample size is 1 liter.

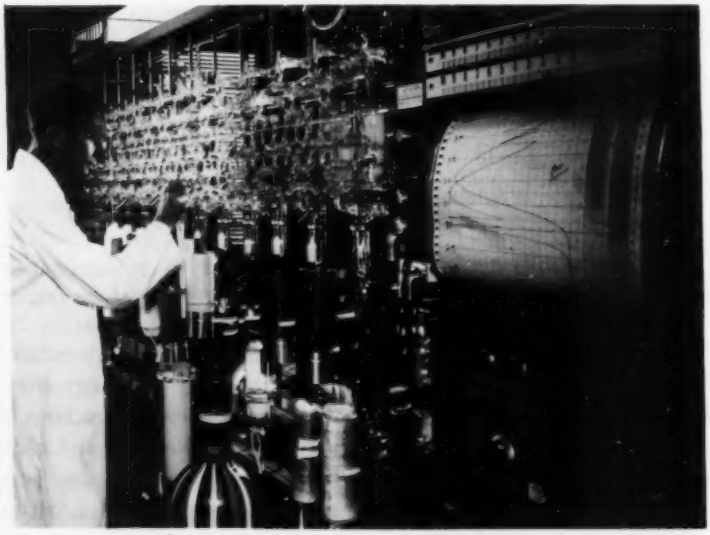

Figure 2. Chart recorder and ionization counter apparatus at Lawrence Radiation Laboratory

Helium is passed through the column as the temperature is progressively raised stepwise. The gases pass through the column in inverse order of their degree of adsorption. For a complete separation, both charcoal and a molecular sieve are employed at temperatures ranging from liquid nitrogen (−240°F) to +600°F.

During the course of an elution, the procedure is monitored using a thermal conductivity detector and an ionization chamber. These are read out on the chart recorder (figure 2). The purified gas is recovered for transfer to a radiation counter.

Two types of counters are used. The "gas-cell," thin-window proportional counter is employed for krypton–85 radioassay. The krypton is contained in small cells that are loaded on a sample changer (figure 3). Each cell, in turn, is rotated underneath the lead shield of the counter, where it is raised to the counting position. Gases containing tritium are placed in internal proportional counting tubes and become a part of the fill gas in the active volume of the tube (figure 4). These tubes are counted inside a shielded cave.

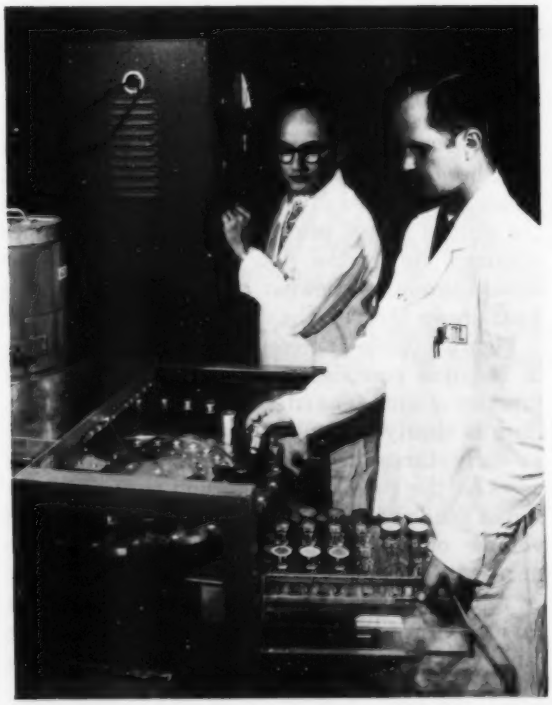

Figure 3. Gas cells containing radioactive krypton–85 separated from Gasbuggy chimney gas samples, being loaded on an automatic sample changer

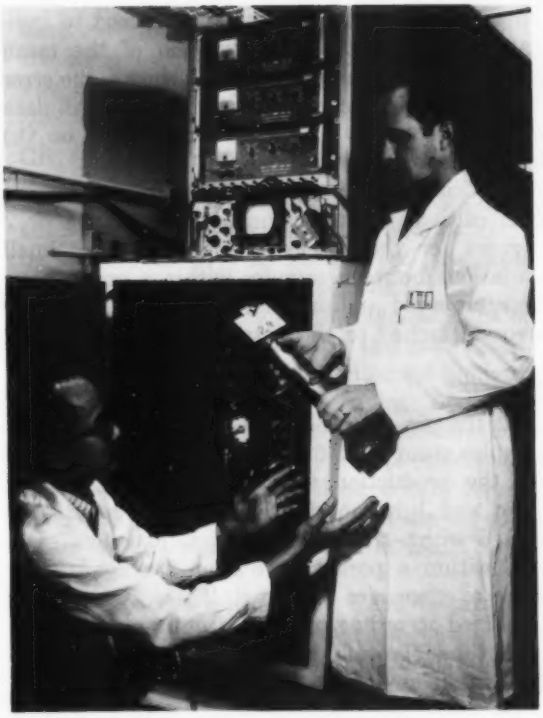

Figure 4. Internal proportional counter containing tritium contaminated gas separated from Gasbuggy chimney gas samples, being placed in a shielded arrangement

Systematic errors which may be present in these determinations are not estimated. The calibration factors for the two counting methods are known to within a few percent and were determined by counting gases of known radioactivity. A conservative estimate of the uncertainty in the absolute value of these measurements is, therefore, less than ±10 percent of the value given. Precision of these determinations is improved by our standard practice of counting replicates. Results of duplicate counts are averaged to obtain the final result and an estimate of its reliability. The numbers to be presented here have individual standard deviations of less than 3 percent. Precision within a group of samples includes this uncertainty but is primarily determined by real variations in sample composition between samples. As will be seen, this variation is significant for hydrogen but much less so for the other gases of interest. In the data which follow, the precision of the measurements is indicated by inclusion of ±1 sigma (standard deviation of the mean) as the indicated uncertainty.

In the plotted data, error bars are used to indicate precision, standard deviation of the mean included. Where no such bars are shown, the error bars lie within the plotted point system. All data are related to cavity gas after air (based on O_2) was removed from the sample.

Analytical errors vary according to the percent composition, but are generally less than 1 or 2 percent for the species of interest here. Small variations between samples within a group have been observed and are the primary source of the errors attached to the data.

Sampling

At the present time, data are available from 16 samples grouped in five sampling periods. Except for the production testing which occurred last June and July, no significant variation was observed within a sampling period. Therefore samples within a period have been averaged. Only these averages are presented. These averages are identified according to the mid-point of their sampling time following the detonation (December 10, 1967) as follows:

1st day samples: Four samples were obtained as a result of leakage through the cable conduits to the sealed annulus of the emplacement hole. While these samples were gathered about 1 day after the detonation, the actual time of their separation from the body of chimney gas is most certainly much shorter. They probably represent the chimney gas composition shortly after chimney collapse. Two were suitable for radiochemical analysis. However, these were 85 percent air. Therefore, the errors of the chemical analyses are magnified for the 15 percent of the sample deemed "cavity gas". In spite of this, the results do seem to provide useful information and to fit well with the main body of information obtained from the other groups of samples.

34th day samples: Seven samples were taken between 32 and 36 days after detonation when communication with the chimney by GB-ER[3] had been established. Five of these have been analyzed —two downhole samples and a surface sample taken before 3×10^5 ft³ of gas was flared and one downhole and one surface sample after flaring. No significant differences in the results reported were seen between surface and downhole samples, or between samples prior to and following the flaring. The air correction of sample composition to obtain cavity gas composition was a few percent for these samples.

79th day samples: Of the four samples taken, results from one surface and one downhole sample following flaring of 4×10^4 ft³ of gas are reported. As was the case of 34 days, no significant difference between samples was observed. Downhole sampling has therefore been eliminated. The air correction was only 1 percent for these samples.

134th day samples: Results of the two surface samples taken after 4×10^3 ft³ of gas were flared are included in this report. No air correction was required.

203rd day samples: Data points at 203 days are taken from the first good sample obtained during the extended flow test. Approximately 5×10^6 ft³ of gas had been flared prior to sampling. Samples were taken at intervals of 5×10^6 ft³ or daily. Analytical results from six of these will be reported. No air correction was required for these samples.

Gasbuggy analytical results

For convenience and presentation the samples have been divided into two time periods. The first group is composed of those samples taken during the shut-in period prior to flow testing. Samples obtained during the flow testing comprise the second group. Somewhat arbitrary curves have been drawn through the data points.

Figure 5 (table 1) presents the observed changes in chemical composition of the cavity gas as a function of time. The effect of temperature equilibrium is clearly evident. Light gases predominate at early times, moving towards more complex gases as the chemical equilibrium shifts. Plotted across the lower portion of the graph is the total volume of gas with which the krypton–85 is mixed. Its constancy within analytical uncertainty is remarkable. Evidently equilibration of the cavity with formation pressure occurred quite rapidly and has been maintained throughout the shut-in period.

The total gas volume was obtained by dividing the total krypton–85 by the krypton–85/ft³ NTP (normal temperature and pressure) determined

[3] GB–ER, Gasbuggy–Emplacement re-entry hole, a post-detonation hole drilled directly through the original emplacement hole.

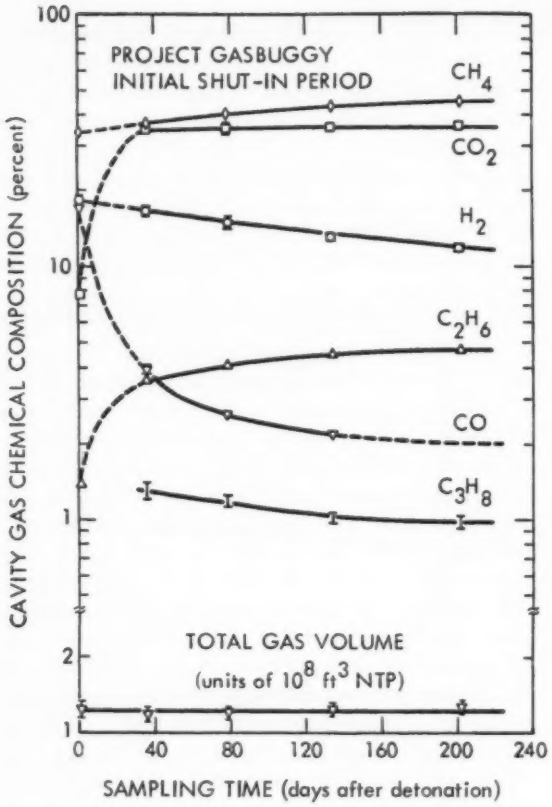

Figure 5. Chemical composition of cavity gas as a function of time after detonation

from radiochemical analysis of the samples. Total krypton–85 is estimated at 350 curies according to the anticipated performance of the nuclear explosive (*1*).

The rapid increase in CO_2 and the corresponding decrease in CO suggests that the water-gas reaction:

$$CO + H_2O \rightarrow CO_2 + H_2 \qquad (1)$$

reaches equilibrium at early times.

The gradual decrease in H_2 concentration appears to be due to the reaction:

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \qquad (2)$$

which is observed to proceed slowly toward equilibrium throughout the sampling period. In addition, natural gas from the formation has entered the cavity to maintain constant pressure. Adding reactions (1) and (2) produces:

$$3H_2 + CO \rightarrow CH_4 + H_2O \qquad (3)$$

Note that CO_2 does not enter and is indeed constant over the major sampling period. H_2 and CO are being used up while methane is increasing. The observed increase in ethane concentration may be due to a reaction such as:

$$CH_4 + CO + 2H_2 \rightarrow C_2H_6 + H_2O \qquad (4)$$

The observed decrease in propane may or may not be significant. Variation such as that seen can be attributed to fractionation of the sample during the later sampling periods.

Another way to view the chemical data is in terms of totals of elements in the gas (figure 6). The total gas volume is plotted across the bottom of the figure to provide a base line. Above it, in the center of the figure are the concentrations of the elements of interest. Because of the constancy of the total gas volume, these curves represent totals equally well. The curves at the top of the figure are chemical composition in terms of atom percent.

This figure illustrates the trend toward more complex molecules by the chemical reaction processes coupled with the influx of formation gases

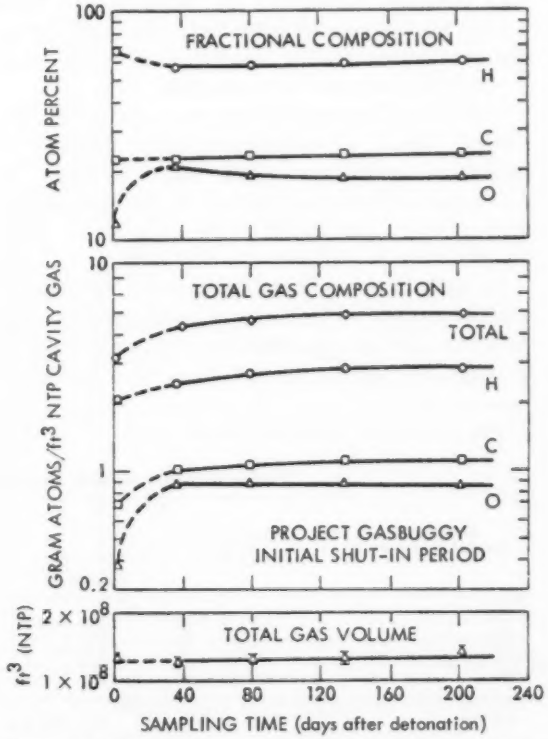

Figure 6. Elemental composition of cavity gas in a function of time after detonation

Table 1. Chemical composition of Gasbuggy cavity gases

Sampling time (days after detonation)	Mole percent					
	H_2	CH_4	C_2H_6	C_3H_8	CO	CO_2
1	18.1 ± 0.6	34.0 ± 0.5	1.37 ± 0.02	—	17.1 ± 0.4	7.8 ± 0.2
36	16.8 ± .4	36.9 ± .8	3.00 ± .06	1.3 ± 0.1	3.9 ± .2	35.8 ± .5
79	15.2 ± 1.0	40.1 ± 2.0	4.1 ± .2	1.19 ± .04	2.6 ± .1	35.8 ± 1.6
134	13.2 ± .1	43.2 ± .7	4.5 ± .1	1.02 ± .05	2.20 ± .04	35.3 ± .7
203	12.0 ± .2	44.2 ± .7	4.7 ± .2	.97 ± .05	—	36.2 ± .7

to maintain a constant volume of gas within the chimney. Note that the fraction of hydrogen decreases even though the total number of hydrogen atoms increases early.

The increase in oxygen at early time is due to the production of CO_2 by the water-gas reaction (1). The decrease at late time can be accounted for by invoking reaction (3).

The radiochemical results for tritium in hydrogen, methane, and ethane, are plotted on figure 7 (table 2). Again, total gas volume is plotted along the base line for reference. The observed gas volume of 1.2×10^8 ft³ NTP can be contained in $2.1 \pm 0.1 \times 10^6$ ft³ void at 150°F and 950 psig[4] (the observed conditions on January 23). Such a void was estimated from data obtained during the production testing, implying that the total krypton-85 estimate is reasonable.

The actual krypton-85 data seem to be moving toward lower concentrations but because of analytical errors associated with the data no conclusion can be reached as to the significance of this trend. The best fit to the data within these uncertainties is probably the line shown.

At early times a large fraction of the gaseous tritium existed in the form of hydrogen gas. The data point for gaseous trituim at 1 day corresponds to some 30 percent of the total of 4 grams of

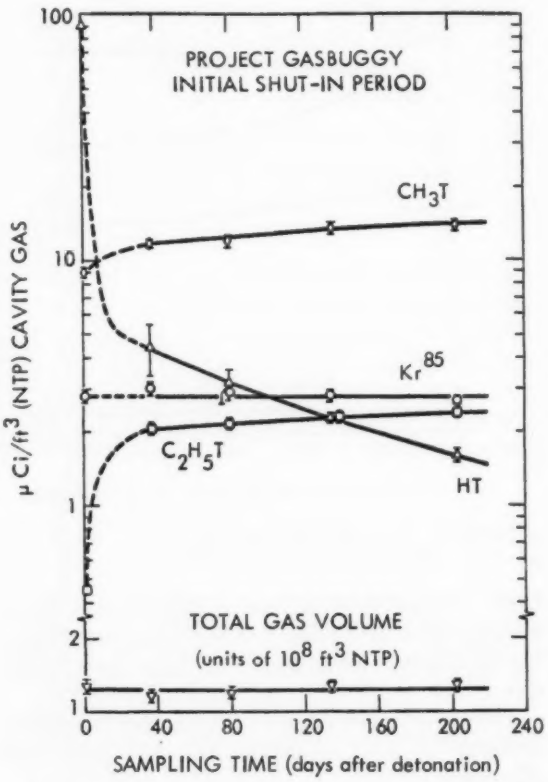

Figure 7. Radionuclide concentrations in cavity gas as a function of time after detonation

[4] psig–pounds per square inch gauge.

Table 2. Radionuclide concentration in Gasbuggy cavity gases

Sampling time (days after detonation)	Total gas volume (10^8 ft³ NTP)	Radionuclide concentration[a] (μCi/ft³ of cavity gas)				
		Krypton-85	HT	CH_3T	C_2H_5T	Total tritium
1	1.25 ± 0.08	2.8 ± 0.2	91 ± 1	8.9 ± 0.1	0.45 ± 0.01	100 ± 1
36	1.17 ± .07	3.0 ± .2	4.4 ± 1.1	11.7 ± .1	2.06 ± .09	18 ± 1
79	1.20 ± .08	2.9 ± .2	3.1 ± .5	12.0 ± .7	2.15 ± .06	17 ± 1
134	1.24 ± .06	2.8 ± .1	2.3 ± .1	13.6 ± .7	2.3 ± .1	18 ± 1
203	1.28 ± .07	2.7 ± .1	1.6 ± .1	13.9 ± .7	2.4 ± .1	18 ± 1
Average	1.23 ± 0.04	2.8 ± 0.1				[b](18 ± 0.8)

[a] Errors quoted are 1-standard deviation of the mean of averaged measurements.
[b] Average does not include the 1 day sample result.

tritium assumed present in the post-shot chimney. During the first month the HT level dropped quite rapidly and continued to decline at a slower rate. Prior to the time re-entry of the chimney well was accomplished, tritiated methane became the principle contaminant of the chimney gas. About 5 percent of the total tritium remains gaseous at late times. Presumably the other 95 percent is in the form of water. No meaningful tritiated water results can be reported. Obtaining a representative sample of water in the chimney gas is extremely difficult. The actual numbers range from about a microcurie per cubic foot of cavity gas to 0.001 of that value, the variation being due primarily to dilution of the tritiated water in the sample by tritium-free water within the cavity and re-entry well casing coming from the overlying aquifers.

Iodine–131, a potential problem radionuclide at early times, was not seen in any of the samples. An upper limit of 10^{-3} μCi/ft^3 (NTP) of this radionuclide existing as a gas within the chimney appears conservative. No other radionuclides have been detected which would cause a problem at times longer than a few months. Argon–37 produced by neutron activation of the calcium in the rock is the only other radionuclide now prominent in the gas. Its initial concentration was about 120 μCi/ft^3 NTP. Due to its half-life (35.4 days) the argon–37 concentration is now less than that of krypton–85.

Analysis of a sample obtained from GB–2R[5] is not yet complete, but does indicate the presence of a small quantity of cavity gas in the formation out to at least 300 feet.

Changes in the concentrations of the tritiated species appear to follow the trends observed for chemical compositions, with the exception that the decrease of tritiated hydrogen is more marked than the corresponding decrease in hydrogen gas. Equilibrium reaction such as the water–gas reaction (1) provide a path whereby tritium can exchange with hydrogen in water, reducing the tritium concentration. The overall effect is that the ratio of tritium to hydrogen tends to equalize in all hydrogen containing species participating in the exchange. The degree to which this is observed depends on the exchange rate.

The rapid initial decrease in HT concentration can therefore be explained using the water–gas reaction:

$$HT + CO_2 \rightarrow HTO + CO \qquad (5)$$

and reactions such as (2) and (4) can be used to explain the observed increases in tritiated methane and ethane.

In figure 8, specific activities are compared for the tritiated species. These curves demonstrate the trend toward a uniform tritium to protium ratio. The HT/H_2 ratio is seen to drop quite rapidly as the water-gas reaction approaches equilibrium and to change slope as the slower chemical reactions begin to dominate. The rapid decrease observed indicates that the T/H in cavity water was quite low, and is consistent with the production of CH_4 and C_2H_6 by reactions such as (2) or (4).

The fact that both the CH_3T and C_2H_5T curves appear to be flat over the entire sampling period is not contradictory. They are being produced by

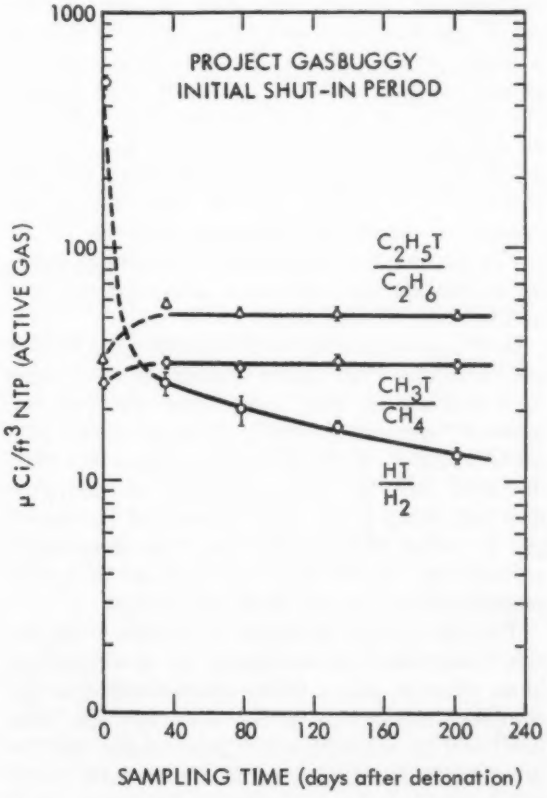

Figure 8. Specific activities of tritiated species as a function of time

[5] Second Gasbuggy re-entry hole drilled about 300 feet from GB–ER.

hydrogen of nearly comparable specific activity. In fact, the samples at 134 days show very nearly the classical 1:2:3 ratio for the three curves. Presumably the eventual downward trend should appear when the HT is further reduced by exchange with water. The fact that exchange equilibrium existed at 134 days and that the HT/H_2 ratio is still decreasing may imply entry of non-tritiated water into the chimney.

Isotopic effects are not considered here but would also tend to reduce the tritium as elemental hydrogen in favor of water at low temperatures.

Changes in chemical composition of the gas during the 11-day flow test which occurred during June–July 1968 are plotted on figure 9. Logarithmic increases with flow for components of natural gas are complimented by corresponding decreases for gases solely of cavity origin. Results plotted cover the flaring period at 5×10^6 ft³ per day nominal flow.

The produced gas is nearly like cavity gas in composition. About one third of the original cavity gas was removed by dumping two fifths of a cavity volume of gas. On the average only 17 percent of the produced gas came from outside the chimney. At this rate a factor of 10 reduction in contamination of the chimney gas can be achieved by flaring about two chimney volumes (2.5×10^8 ft³ NTP). Further experiments are needed to define the long-term behavior of the cavity flushing and to establish a consistent model for estimating the fraction of cavity gas removed as a function of flow rate.

Radiochemical analysis of these samples are not yet complete. Preliminary assessment of changes in concentration that have been observed, do, however, seem to generally fit those shown here for CO_2 and H_2. They do, however, show a marked deviation from the lines established at the higher flow indicating much more dilution of the cavity gas by influx of formation gas. This observation corresponds to the observed increase in cavity pressure during the low-flow rate flaring.

The gas quality program at Lawrence Radiation Laboratory is continuing its investigations in an effort to gain a better understanding of the complex interactions of the Gasbuggy gas with itself and its environment. These results, and the interpretations which can be drawn from them, will be publicly available in the future.

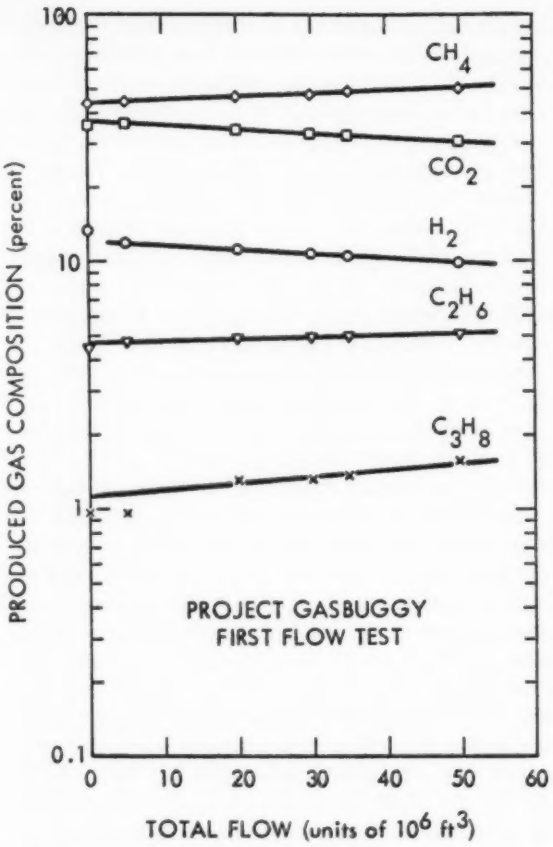

Figure 9. Changes in chemical composition of gas during 11-day flow test in June–July 1968

Acknowledgement

The authors wish to acknowledge the assistance of Mr. R. Crawford of the Lawrence Analytical Chemistry Group who performed the chemical analysis by mass spectrometry.

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Radioecological Surveillance of the Waterways Around a Nuclear Fuels Reprocessing Plant[1]

N. I. Sax, Paul C. Lemon, Allen H. Benton, and *Jack J. Gabay*[2]

A 3-year study of the aquatic ecosystem around a nuclear fuels reprocessing plant, located in western New York State, has been conducted to find and evaluate natural indicators of environmental contamination. The study covered preoperational and early post-operational phases. The ecological vectors selected for study were algae, silt, and fish, all from Cattaraugus Creek and its tributaries. Samples were collected at several points upstream and downstream from the plant effluent and quantitatively analyzed by gamma-ray spectrometry. All vectors analyzed indicated process of uptake and concentration of ruthenium-rhodium–106, cesium-137, cesium-134, and/or zirconium–niobium–95, and sometimes cobalt–60.

In addition, the concept of using natural indicators not native to the streams under study was tested by translocating fresh water clams from Chautauqua Lake, 60-miles southwest of the site, and placing them in the streams around the plant. The clams not only thrived in their new environment but upon analysis showed definite interaction by concentration of the above radioisotopes with the shells showing approximately twice the radioactivity of the soft parts of the clams. This concept might prove to be a sensitive indicator of environmental contamination.

In April 1966, the world's first commercial nuclear fuels reprocessing plant, located in the southwestern part of New York State, became operational. Prior to and since then, the Radiological Sciences Laboratory of the Division of Laboratories and Research, New York State Department of Health, with the cooperation of the State University of New York, has been conducting an ecological study of the effect on the aquatic ecosystems in that area with a view to finding the most suitable vectors as natural indicators of environmental contamination.

Description of sources

The facility is a multipurpose plant capable of processing any type of nuclear fuel element from which the fuel can be reduced to a nitric acid solution. The baseline process is a Purex solvent-extraction method designed for processing, at a capacity of 1,000 kg/day of uranium enriched <3 percent in the form of UO_2 or uranium metal. Fuels must be cooled 150 days after removal from a reactor before they can be processed (*1*). In addition, a burial site, operational since 1963, is maintained for the storage of high, intermediate, and low-level radioactive wastes from the plant and offsite users.

Study area

Study of the aquatic ecosystem centers on two waterways flowing through and around the reprocessing plant site (figure 1). Buttermilk Creek flows through the site in the southeast to northwest direction and empties into Cattaraugus Creek just outside the extreme northwest corner of the site. Cattaraugus Creek flows in a westerly direction and, after many convolutions, eventually empties into Lake Erie. Both streams are fed by many tributaries. The only important tributary, considering radionuclide inventory in the streams, is Erdman Brook, which serves as a receptor for runoff from the burial site and effluent discharge from the reprocessing plant.

The physical and chemical characteristics of a portion of Cattaraugus Creek were studied to determine some of the ecological conditions to which organisms living in the stream must adapt in order to survive. Determination of the oxygen

[1] This investigation was supported by U.S. Public Health Service Grant RH 412, National Center for Radiological Health.

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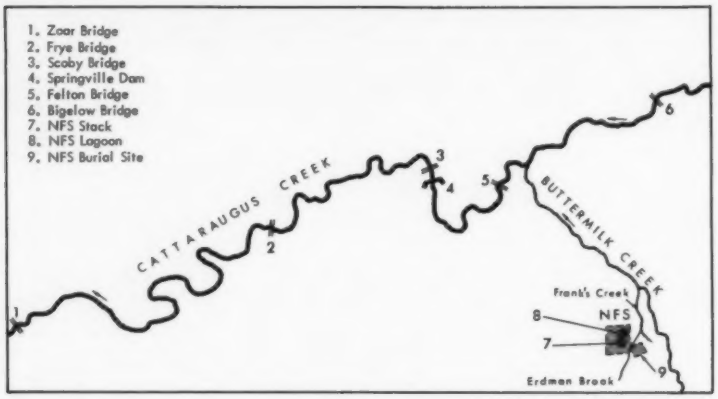

Figure 1. Waterways around the reprocessing plant, burial site, and sampling stations

and carbon dioxide served as a measurement of the relative extent of organic pollution and permitted evaluation of the distribution of organisms in the stream. This knowledge would be of value in planning future experiments. Quantitative data on stream flow, dissolved oxygen concentrations, and carbon dioxide concentrations were taken at Felton Bridge (figure 1) during the summer of 1967. Data were secured by standard methods (*2*); surface velocity was determined with a floating object and stream flow was determined by using the formula: R = W D a V

where R = volume in ft^3/sec;
W = width in ft;
D = average depth in ft;
a = correction factor for substrate;
and, V = surface velocity in ft/sec.

During a period of average flow, the rate was estimated at 54,000 gallons/minute. After a heavy rain, the flow was estimated at 132,500 gallons/minute, indicating the rather wide variation in flow which the creek may undergo. Further, the latter estimate is not representative of a maximum flow since it would have been quite impossible to make the necessary measurements during peak flow following a heavy rain. It is clear that wide fluctuations in flow present one of the major ecological factors of this particular creek, and one to which organisms living in the creek must adapt.

Oxygen and carbon dioxide determinations were also made at the Felton Bridge sampling point. These parameters were determined by standard methods described by Welch (*3*). In swift current the stream contained 4–5 ppm dissolved oxygen and 2–3 ppm of carbon dioxide. Backwaters were found to contain 2–3 ppm of dissolved oxygen and 10–11 ppm of carbon dioxide.

Sampling and analytical methods

Study of the streams around the reprocessing plant permits a meaningful relationship to be derived concerning the dispersion of radioactivity released into the stream and concentration by various organisms residing therein. In reality, there are two streams plus tributaries which must be considered as one system. Sampling points on Erdman Brook and Buttermilk Creek upstream from the plant, and on Cattaraugus Creek upstream from the confluence with Buttermilk Creek are considered control points. All downstream sampling points are considered reaction points.

A simple ecological chain, consisting of water, algae, silt, and fish, was set up, and such samples were routinely collected at the designated sampling sites. Analysis by gamma-ray spectrometry offered unique advantages in that quantitative information on the presence of several radionuclides could be obtained from a single sample with little prior processing.

Liquid samples were analyzed without processing except for transfer to a counting container. Solid samples were blended before transfer. The standard counting container was a 2-liter Marinelli beaker. Samples up to 300 ml for liquids (300 g for solids) were accommodated by placing them

on the top of the crystal. Integral-line NaI (Tl) crystal detectors, 3 by 3 inches, were used in conjunction with multichannel analyzers operated in the 256 channel mode. Standard readouts were typewriter, X–Y plotter, and punched paper tape, which was converted to punched cards for computerization. Data were quantitated by using inverted matrix techniques. Routinely, standard matrices were prepared for each sample type. However, all spectra were visually examined and special matrices were prepared to accommodate nonroutine spectra.

The occurrence of complex spectra containing radionuclides whose photopeaks coincide or overlap makes electronic resolution extremely difficult. The presence of both zirconium–niobium–95 and cesium–134 in our samples was anticipated; cesium–134 has two photopeaks (0.605 and 0.796 MeV) which coincide with photopeaks for cesium–137 (0.662 MeV) and zirconium–niobium–95 (0.724, 0.757 and 0.765 MeV). Significant concentrations of any of these nuclides can effectively mask or confuse the identity of others.

The presence of both zirconium–niobium–95 and cesium–134 in the aquatic environment was qualitatively confirmed in silt samples by chemical isolation of radiozirconium and radiocesium followed by gamma-ray spectral analysis of each fraction. Semiquantitative analysis of the data indicated that each radionuclide was present in approximately equal concentration. No attempt was made to relate the fractionation ratios to other silt samples, or to extrapolate to other sample types such as algae or fish. Therefore, all such data are reported as ^{95}ZrNb–^{134}Cs, indicating that either or both of these radionuclides are present.

Results and discussion

Water

Radioactivity from liquid effluents released directly into the stream will tend to be dispersed and diluted. Although no significant radionuclide concentration was anticipated, stream water was sampled and analyzed regularly to provide a frame of reference for other ecological samples. Results of radioactivity in the streams are given in table 1.

Algae

Algal samples were collected at a number of points along the stream during the summer of 1967 and analyzed (table 2). In general, the radionuclide concentration decreased as a function of distance from the source (figure 2).

Algae are well known for their ability to concentrate certain radionuclides. Lackey (*4*) found that the gross count rate for *Oedogonium* to be 104 times that for the surrounding water. Blinks and Nielsen (*5*) determined that *Hydrodictyon* may accumulate potassium to 4×10^3 times that in the surrounding water. Concentration of strontium-90 by green algae and by the water flea (*Daphnia*), using green algae as a food source has been reported (*6–8*). Williams and Swanson (*9*)

Table 1. Radioactivity in streams around Nuclear Fuel Services site, 1965–1967

Sampling station	Collection period	Radionuclide concentration (pCi/liter)			
		^{106}Ru-Rh	^{137}Cs	^{95}Zr-Nb-^{134}Cs	^{60}Co
Control points:					
Buttermilk Creek, upstream	12/65– 3/66[a]	[b]0 (26)	5 (26)	2 (26)	0 (26)
	6/67–12/67	40 (6)	3 (6)	0 (6)	1 (6)
Bigelow Bridge	12/65– 3/66[a]	0 (11)	5 (11)	1 (11)	0 (11)
	4/66–12/66	0 (14)	6 (14)	3 (14)	0 (14)
	6/67–11/67	2 (6)	5 (6)	0 (6)	2 (6)
Erdman Brook upstream[c]	5/67–12/67	150 (19)	10 (19)	0 (19)	20 (19)
Reaction points:					
Buttermilk Creek, downstream	12/65– 3/66[a]	0 (3)	1 (3)	6 (3)	0 (3)
	6/67–12/67	1,000 (18)	100 (18)	10 (18)	10 (18)
Springville Dam	12/65– 3/66[a]	0 (11)	1 (11)	0 (11)	0 (11)
	4/66–12/66	0 (22)	10 (22)	4 (23)	0 (22)
	5/67– 9/67[d]	100 (3)	10 (3)	0 (3)	4 (3)

[a] Preoperational samples, taken before radioactivity was introduced into environment by NFS.
[b] Numbers in parentheses indicate number of samples averaged.
[c] Erdman Brook, upstream is not truly a control point. It is upstream of the point where plant effluents are discharged into the brook; but is downstream to run-off from the burial site. It is therefore, an indicator of the contribution of the burial site to the radionuclide inventory in the stream.
[d] Continuous monthly composite.

Table 2. Average radionuclide concentration in algae, 1967

Sampling station	Collection period	Radionuclide concentration (pCi/kg wet weight)			
		^{106}Ru-Rh	^{137}Cs	^{95}Zr-Nb-^{134}Cs	^{60}Co
Control point:					
Bigelow Bridge	7/67–8/67	*7 (9)	15 (9)	50 (9)	70 (9)
Reaction points:					
Buttermilk Creek, downstream	8/67	344,000 (1)	50,400 (1)	9,100 (1)	1,100 (1)
Felton Bridge	7/67–8/67	54,000 (2)	69,900 (2)	13,400 (2)	760 (2)
Springville Dam	7/67–8/67	45,600 (6)	23,400 (6)	5,700 (6)	350 (6)
Frye Bridge	7/67	10,200 (3)	5,000 (3)	1,350 (3)	180 (3)
Zoar Bridge	7/67	11,800 (2)	5,100 (2)	1,200 (2)	190 (2)

* Numbers in parentheses indicate number of samples averaged.

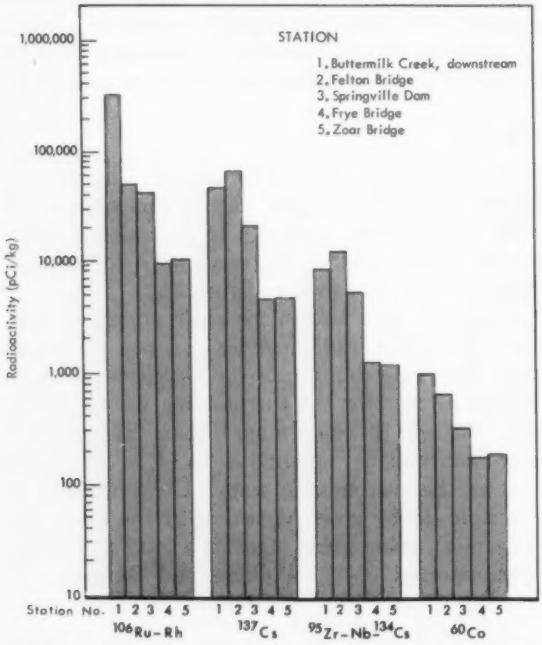

Figure 2. Concentration of various radionuclides in algae as a function of distance from the source

found concentration of cesium–137 by *Rhizoclonium* to be 1.5×10^3 times that of its environment. Williams (*10*) reported that *Chlorella* concentrated radiocesium 46 to 59 times that in the surrounding medium. Interestingly, dead *Chlorella* cells showed a similar concentrating ability.

It would thus appear that a period of algal bloom, followed by death and decay of the algae, might cause a very significant concentration of radiocesium and might produce a rather high level of radioactivity on the bottom. Although the upper levels may quickly be decontaminated, the bottom fauna is exposed to a rapidly increasing level of concentration, mostly bound cesium, in the dead organisms and detritus on the bottom.

The fact that algae might retain high radionuclide levels even after death and settling suggests that the concentration of such materials in silt might be unusually high. It is also established that adsorption of radioactive particulates may take place on tiny silt particles in the water, and that settling out of these particles will then concentrate the radionuclides concerned. Studies on bottom dwelling organisms in the Clinch River and White Oak Creek indicate that such organisms receive an average dose 20 to 1,000 times that from naturally occurring radiation (*11*).

Silt

Samples of stream bottom silt were collected at all the water sampling points as well as two additional sites. Collection dates extend from August 1966 to October 1967. Silt radioactivity (table 3) tends to show, again, the general decline with increased distance from the point of introduction (figure 3).

The contribution from burial site run-off to the stream inventory (table 4) is of particular interest since effluent discharge from the reprocessing plant and run-off from the burial site are apparently unrelated. The water and silt data from Erdman Brook, upstream or plant effluent discharge but downstream from the burial site runoff, and Buttermilk Creek, downstream from plant effluent discharge (figure 1) provide a means for evaluation. Dilution factors, due to the larger amount of water in Buttermilk Creek, are not known, thereby tending to make the radionuclide contribution to the stream inventory from the burial site, as based on the water data, suspect. However, these dilution factors should not significantly influence

Table 3. Radionuclide deposition in stream bottom silt, 1966–1967

Sampling station	Collection period	Radionuclide concentration (pCi/kg wet weight)			
		^{106}Ru-Rh	^{137}Cs	^{95}Zr-Nb-^{134}Cs	^{60}Co
Control points:					
Buttermilk Creek, upstream	8/66–12/66	[a]6,700 (2)	430 (2)	320 (2)	110 (2)
Bigelow Bridge	9/66–10/67	820 (10)	70 (10)	50 (10)	5 (10)
Erdman Brook, upstream[b]	12/66	44,100 (1)	16,500 (1)	5,500 (10)	1,400 (1)
Reaction points:					
Buttermilk Creek, downstream	8/66– 8/67	226,000 (7)	115,000 (7)	120,000 (7)	8,000 (7)
Felton Bridge	9/66–10/67	53,400 (10)	62,000 (10)	12,800 (10)	690 (10)
Springville Dam	9/66–10/67	45,700 (9)	28,800 (9)	7,400 (9)	470 (9)
Frye Bridge	7/67–10/67	36,700 (7)	24,100 (7)	4,500 (7)	360 (7)
Zoar Bridge	9/66–10/67	15,100 (12)	5,300 (12)	1,700 (12)	120 (12)

[a] Numbers in parentheses indicate number of samples averaged.
[b] Erdman Brook is upstream of the point where plant effluents are discharged into the brook; but is downstream to run-off from the burial site. It is, therefore, an indicator of the contribution of the burial site to the radionuclide inventory in the streams.

the radionuclide adsorption onto silt. Table 4 was prepared to compare the data from tables 1 and 3. An estimated percent contribution is offered to assess the contribution of the burial site to the stream inventory.

Although these data are quite preliminary, some relationships are apparent. The percent contribution from the burial site for both water and silt is relatively consistent with respect to ruthenium–106 and cesium–137 activity. The contribution due to the ^{95}ZrNb–^{134}Cs pair is appreciably smaller than that due to the other radionuclides, implying that one of the pair may not be present in the run-off from the burial site.

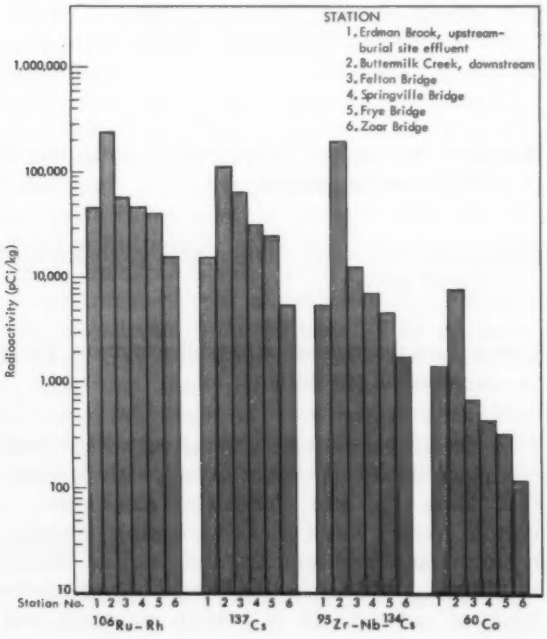

Figure 3. Deposition of various radionuclides on stream bottom silt as a function of distance from the source

Fish

Fish can be an important ecological vector since they, too, are known to concentrate certain radionuclides. Concentration of radiostrontium by freshwater fish has been reported (*12–13*). Kolehmainen et al. (*14*) reported that cesium–137 levels in fish in Finland were inversely related to conductivity of the water. Recent studies on Columbia River fish indicate that they concentrate phosphorus–32 and zinc–65 (*15-16*).

Fish samples were taken by net and prepared for analysis as they were captured without sorting. This provided an ample volume for counting (table 5).

It is interesting to note that preoperational fish samples collected at downstream points indicated significant radionuclide concentration while those at upstream points did not. Since these fish were collected before the reprocessing plant became operational (but after operation of the burial site), contamination from the burial site must be considered the likely source. This again emphasizes the contribution of the burial site to the stream inventory. Of the post-operational samples, all indicated concentration of cesium–137 and probably cesium–134, while some showed concentration of ruthenium–rhodium–106 and/or cobalt–60 as well. This may well be a function of specific species and pointed to the need for a more detailed study of individual species present in the streams.

Table 4. Radionuclide contribution of burial site to stream inventory 1965–1967

Sample type	Sampling point	Radionuclide concentration[a] (pCi/liter or kg wet weight)			
		^{106}Ru-Rh	^{137}Cs	^{95}Zr-Nb-^{134}Cs	^{60}Co
Water	Erdman Brook upstream	150	10	0	20
	Buttermilk Creek, downstream	1,000	100	10	10
Percent contribution		15.0	10.0	0	>100
Silt	Erdman Brook, upstream	44,100	16,500	5,500	1,400
	Buttermilk Creek, downstream	226,000	115,000	120,000	8,000
Percent contribution		19.5	14.3	4.6	17.5

[a] Units are pCi/liter for water samples, pCi/kg for silt samples.

Table 5. Radionuclide uptake by stream fish, 1965–1967

Sampling station	Collection period	Radionuclide concentration (pCi/kg wet weight)			
		^{106}Ru-Rh	^{137}Cs	^{95}Zr-Nb-^{134}Cs	^{60}Co
Control points:					
Buttermilk Creek, upstream	10/27/65[a]	0±20[b]	80±20	20±15	0±15
Bigelow Bridge	10/27/65[a]	0±20	20±15	5±10	0±10
Reaction points:					
Buttermilk Creek, downstream	10/27/65[a]	0±20	1,700±130	240±30	50±20
	8/29/66	0±20	4,000±250	6,100±360	130±30
	8/ 1/67	23,900±2,400	31,100±1,800	7,600±500	350±75
Felton Bridge	10/27/65[a]	0±20	460±50	240±30	50±20
	7/ 5/67	310±350	2,200±180	530±60	7±20
	8/23/67	90±230	410±70	80±30	0±15
	8/24/67	960±280	910±95	240±40	0±15
	8/24/67	370±300	440±240	60±110	0±15
	8/25/67	4,300±630	3,300±260	580±70	20±30
Frye Bridge	7/20/67	4,400±350	1,400±120	250±40	30±30

[a] Preoperational samples.
[b] 2σ counting error.

Fish are varied in their mode of life. Consequently, accumulation of radionuclides by any one group can be quite different from that by another. There are, however, some facts regarding accumulation that apply to fish generally. Uptake of elements may take place from water directly or from the ingestion of food containing concentrated amounts. The manner of uptake of elements by the different types of fish needs considerable study.

Fortunately, there are several common fish species in the streams which can be caught in fair numbers, including some bottom feeders. Five species were deemed abundant enough to be suitable for repeated collection over time:

Notropis cornutus—common shiner abundant in the creek itself.

Semotilus atromaculatus—horned dace, abundant in the backwaters and pools.

Hybopsis micropogon—river chub, common in faster moving waters.

Catostomus commersoni—white sucker, common in deeper waters.

Campostoma anomalum—stoneroller minnow, fairly common in the stream.

Of these, *Campostoma anomalum*, which feeds on algae it scrapes from rocks with a modified lower lip, and *Catostomus commersoni*, a bottom feeder, which sucks up organic material, bottom plants and animals, and detritus, should be of special interest in that they must reflect the levels of radioactivity of bottom materials, and might concentrate certain radionuclides very effectively.

Table 6. Accumulation of radionuclides by translocated clams, 1967

Sampling station	Structure	Radionuclide concentration (pCi/kg wet weight)			
		^{106}Ru-Rh	^{137}Cs	^{95}Zr-Nb-^{144}Ce	^{60}Co
Chautauqua Lake (untreated control)	Shell	0±20[a]	0±20	0±20	0±20
	Soft body	0±20	0±20	0±20	0±20
Buttermilk Creek	Shell	24,800±1,700	5,500±360	1,400±110	170±30
	Soft body	11,900±940	2,400±200	500±60	30±30
Felton Bridge	Shell	4,700±450	550±70	140±20	30±20
	Soft body	6,000±830	480±290	190±100	20±110

[a] 2σ counting error.

Clams

Shellfish have the ability, alone or by means of their aquatic food sources, to concentrate certain stable elements and radionuclides far above the ambient concentration in the water environment. The filter-feeding habit of the clam makes it an excellent biological indicator and adapts it admirably for food chain investigations.

Clams have been reported to concentrate cobalt-60 (*17–18*); iron-59 (*18*); zinc-65 (*19–21*); strontium-90 (*22*), particularly in the calcareous shell (*23*); cesium-137 (*23–24*); and manganese-54 (*25–26*).

Clams are not native to the streams around the reprocessing plant. During the summer of 1967, about 150 freshwater clams (*Lampsilis ventricosa* and *L. siliquoidea*) were collected from Chautauqua Lake, about 60 miles southwest of the plant. They were divided into three lots, one of which was immediately killed and separated into shells and soft parts to be used as controls. One set was placed in Buttermilk Creek about 0.5 miles downstream from the plant. Another set was placed in Cattaraugus Creek at Felton Bridge about 1 mile downstream from the plant. They appeared to thrive in their new habitat and at the end of the summer they were removed from the streams, separated into shells and soft parts and analyzed by gamma-ray spectrometry (table 6). Definite accumulation of radionuclides is indicated.

Conclusions

Our efforts have been largely "range finding" in nature, and much time was spent in becoming familiar with the area and determining the abundance of aquatic life present in the streams.

Preliminary data have been presented to demonstrate the ability of the ecological vectors selected to concentrate radionuclides from their environment. However, they are, as yet, too sparse to permit meaningful relationships to be derived.

Aquatic life probably represents the most rewarding area for ecological assessment of the effects of the reprocessing plant. The translocation of clams, as a biological indicator, holds great promise and should be further pursued. Silt, algae, clams, and fish, particularly bottom feeders such as *Campostoma anomalum* and *Catostomus commersoni* taken in conjunction with each other at periodic intervals might establish a meaningful relationship between radioactivity in algae and silt and concentration by fish and clams.

It appears that enough natural indicators of environmental contamination are available to set up a simple and effective means to maintain surveillance and evaluate the effects of the reprocessing plant upon the stream system.

It remains to establish more exactly the rate and extent of interaction of these indicators to the various radionuclides.

Acknowledgements

The authors wish to acknowledge the efforts of Messrs. R. E. Tillman, K. Sullivan, and R.H. Averill, for collection of samples and determination of stream characteristics. We are also grateful to Mr. J. C. Daly and his staff for analysis of samples and to Mr. J. A. Dapolito for his assistance in the preparation of this manuscript.

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SECTION I. MILK AND FOOD

Milk Surveillance, March 1969

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long term concentration trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN), sponsored by the Bureau of Radiological Health and the Bureau of Community Environmental Management, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments have also initiated local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in or are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations, for these concentrations are 1.16 ± 0.08 g/liter and 1.51 ± 0.21 g/liter for calcium and potassium, respectively. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined in the literature (*4*).

The most recent study was conducted in the spring of 1967, with 40 laboratories participating in an experiment on milk samples containing known concentrations of strontium-90, iodine-131, and cesium-137. Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 18 of these laboratories participated in the experiment.

In the majority of cases, the results for the laboratories fell within the 3-standard deviation limits considered appropriate for the various analyses. Several results were outside the 3-standard deviation limits and the most deviant of these represented biases from the expected values of 20 — 30 percent (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis not only varies among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium–137 are relatively stable over time periods and sampling frequency is not critical. For the case of the short-lived radionuclides, particularly iodine–131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of the radionuclide.

The data presentation will also reflect whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during the period, January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration

of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors of precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision 2-standard deviations
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance for the use of Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8*, *9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result from exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1 liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assump-

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Radionuclide	Critical organ	RPG for individual in the general population (rad/yr)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/yr)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0–200	200–2,000	2,000–20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c] 1.5	.5	[d] 200	0–20	20–200	200–2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0–10	10–100	100–1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0–360	360–3,600	3,600–36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/yr to the bone is estimated to result in a dose of 0.5 rad/yr to the bone marrow.
[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

tions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1- or 2- year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first year total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c] 1,110,000
Strontium-90	Bone marrow			[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered.

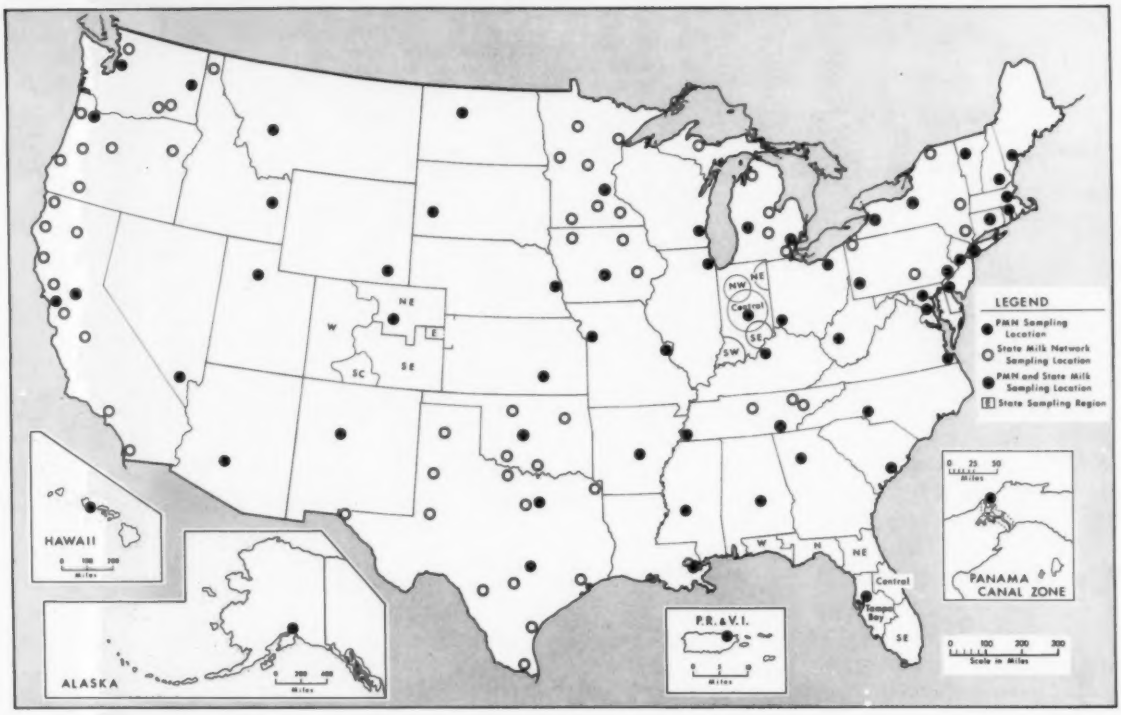

Figure 2. State and PMN milk sampling locations in the United States

the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in a retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-90, iodine-131, and cesium-137, for March 1969 and the 12-month period, April 1968 to March 1969. Except where noted the monthly average represents a single sample for the sampling station. Strontium-89 and barium-140 data have

Table 3. Concentration of radionuclides in milk for March 1969 and 12-month period, April 1968 through March 1969

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	6	8	0 (4)	0	12 (4)	14
Alaska:	Palmer[c]	P	6	6	0 (3)	0	12 (3)	13
Aris:	Phoenix[c]	P	0	1	0 (4)	0	0 (4)	1
Ark:	Little Rock[c]	P	19	20	0 (5)	0	19 (5)	20
Calif:	Sacramento[c]	P	0	1	0 (4)	0	0 (4)	3
	San Francisco[c]	P	2	1	0 (4)	0	0 (4)	2
	Del Norte	P	18	19	0	0	23	21
	Fresno	P	0	0	0	0	0	3
	Humboldt	P	6	4	0	0	0	11
	Los Angeles	P	3	1	0	0	0	4
	Mendocino	P	5	2	0	0	0	4
	Sacramento	P	3	2	0	0	11	5
	San Diego	P	3	0	0	0	0	3
	Santa Clara	P	0	0	0	0	0	6
	Shasta	P	3	3	0	0	0	4
	Sonoma	P	4	2	0	0	0	4
Colo:	Denver[c]	P	3	5	0 (4)	0	0 (4)	5
	West	R	(d)		(e)	(e)	(e)	5
	Northeast	R	(d)		NS	(e)	NS	(e)
	East	R	(d)		NS	(e)	NS	(e)
	Southeast	R	(d)		(e)	(e)	(e)	(e)
	South Central	R	(d)		NS		NS	(e)
Conn:	Hartford[c]	P	6	9	0 (4)	0	8 (4)	12
	Central	P	6	8	0 (4)	0	4	9
Del:	Wilmington[c]	P	8	10	0 (4)	0	5 (4)	9
D.C:	Washington[c]	P	7	9	0 (4)	0	0 (4)	6
Fla:	Tampa[c]	P	8	8	0 (4)	0	39 (4)	63
	West	R	16	13	0	3	19	24
	North	R	16	14	0	0	18	32
	Northeast	R	10	9	0	2	64	81
	Central	R	9	9	0	1	90	84
	Tampa Bay area	R	9	8	0	0	41	71
	Southeast	R	10	9	0	0	78	111
Ga:	Atlanta[c]	P	11	14	0 (4)	0	18 (4)	20
Hawaii:	Honolulu[c]	P	2	4	0 (4)	0	0 (4)	2
Idaho:	Idaho Falls[c]	P	6	6	0 (4)	0	7 (4)	9
Ill:	Chicago[c]	P	8	9	0 (5)	0	6 (5)	10
Ind:	Indianapolis[c]	P	7	8	0 (4)	0	11 (4)	7
	Northeast	P	5	11	0	0	5	11
	Southeast	P	3	10	0	0	15	14
	Central	P	4	9	0	0	10	10
	Southwest	P	6	9	0	0	15	13
	Northwest	P	8	10	0	0	15	13
Iowa:	Des Moines[c]	P	7	6	0 (4)	0	3 (4)	4
	Iowa City	P	7	7	0 (2)	0	13 (2)	8
	Des Moines	P	6	6	0	0	3 (4)	4
	Spencer	P	6	6	0	0	20	6
	Charles City	P	NS		NS		NS	
Kans:	Wichita[c]	P	9	8	0 (4)	0	2 (4)	4
Ky:	Louisville[c]	P	10	12	0 (3)	0	13 (3)	7
La:	New Orleans[c]	P	16	19	0	0	4	22
Maine:	Portland[c]	P	10	12	0 (5)	1	16 (5)	27
Md:	Baltimore[c]	P	6	10	0 (4)	0	7 (4)	8
Mass:	Boston[c]	P	10	12	0 (4)	0	20 (4)	24
Mich:	Detroit[c]	P	8	9	0 (4)	0	14 (4)	11
	Grand Rapids[c]	P	11	11	0 (5)	0	17 (5)	15
	Bay City	P	NA		(e)	(e)	0 (5)	8
	Charlevoix	P	7	6	(e) (5)	(e)	15 (5)	10
	Detroit	P	5	5	(e) (4)	(e)	6 (4)	5
	Grand Rapids	P	7	6	(e) (5)	(e)	16 (5)	10
	Lansing	P	NA	4	(e) (2)	(e)	0 (2)	3
	Marquette	P	11	8	(e) (3)	(e)	28 (3)	27
	Monroe	P	3	3	(e) (3)	(e)	0 (3)	1
	Grand Haven	P	7	7	(e) (4)	(e)	8 (4)	6
Minn:	Minneapolis[c]	P	9	12	0 (4)	0	13 (4)	14
	Bemidji	P	16	16	0	0	19	25
	Mankato	P	9	6	0	0	11	0
	Rochester	P	8	9	0	0	0	0
	Duluth	P	NS	20	NS	0	NS	32
	Worthington	P	5	6	0	0	13	0
	Minneapolis	P	10	12	0	0	0	15
	Fergus Falls	P	7	10	0	0	0	11
	Little Falls	P	9	10	0	0	0	16
Miss:	Jackson[c]	P	11	16	0 (4)	0	9 (4)	16
Mo.:	Kansas City[c]	P	6	7	0 (4)	0	0 (4)	3
	St. Louis[c]	P	7	9	0 (4)	0	4 (4)	5
Mont:	Helena[c]	P	4	4	0 (3)	0	8 (3)	9
Nebr:	Omaha[c]	P	5	6	0 (4)	0	2 (4)	5
Nev:	Las Vegas[c]	P	3	1	0 (4)	0	0 (4)	2
N.H:	Manchester[c]	P	7	13	0 (4)	0	19 (4)	33
N.J:	Trenton[c]	P	8	10	0 (4)	0	14 (4)	11
N. Mex:	Albuquerque[c]	P	0	2	0 (5)	0	2 (5)	0

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for March 1969 and 12-month period, April 1968 through March 1969—Continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES—Continued								
N.Y:	Buffalo[c]	P	7	8	0 (4)	0	12 (4)	11
	New York City[c]	P	8	12	0 (5)	0	16 (5)	16
	Syracuse[c]	P	7	9	0 (4)	0	14 (4)	9
	Albany	P	5	8	0 (4)	0	0 (4)	0
	Buffalo	P	3	0	0 (2)	0	0 (2)	0
	Massena	P	9	11	10 (2)	0	21 (2)	22
	Newburg	P	8	12	0 (5)	0	0 (5)	0
	New York City	P	8	12	0 (5)	0	0 (5)	0
	Syracuse	P	8	9	0 (3)	0	0 (3)	0
N.C:	Charlotte[c]	P	13	15	0 (5)	0	11 (5)	12
N. Dak:	Minot[c]	P	9	11	0 (5)	0	8 (5)	14
Ohio:	Cincinnati[c]	P	8	9	0 (4)	0	5 (4)	6
	Cleveland[c]	P	8	10	0 (4)	0	9 (4)	9
Okla:	Oklahoma City[c]	P	3	9	0 (4)	0	6 (4)	7
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Ore:	Portland[c]	P	5	7	0 (4)	0	7 (4)	13
	Baker	P	2	3	(e)	(e)	17	6
	Coos Bay	P	5	9	(e)	(e)	(e)	15
	Eugene	P	6	4	(e)	(e)	(e)	14
	Medford	P	4	3	(e)	(e)	30	12
	Portland composite	P	3	5	(e)	(e)	(e) (4)	8
	Portland local	P	6	5	(e)	(e)	(e) (4)	8
	Redmond	P	4	3	(e)	(e)	(e)	4
	Tillamook	P	7	7	(e)	(e)	0	26
Pa:	Philadelphia[c]	P	10	10	0 (4)	0	6 (4)	8
	Pittsburgh[c]	P	10	10	0 (5)	0	10 (5)	11
	Dauphin	P	8	8	0	0	19	19
	Erie	P	11	12	0	0	14	23
	Philadelphia	P	6	10	0	0	16	17
	Pittsburgh	P	8	12	0	0	19	16
R.I:	Providence[c]	P	8	11	0 (4)	0	15 (4)	19
S.C:	Charleston[c]	P	9	13	0 (4)	0	22 (4)	25
S. Dak:	Rapid City[c]	P	9	9	0 (5)	0	3 (5)	10
Tenn:	Chattanooga[c]	P	9	13	0 (5)	0	12 (5)	13
	Memphis[c]	P	7	11	0 (4)	0	2 (4)	6
	Chattanooga	P	11	11	0 (5)	0	17 (5)	17
	Clinton	P	12	14	0	0	19	19
	Knoxville	P	8	10	0 (2)	2	12 (2)	13
	Nashville	P	10	9	0 (2)	0	11 (2)	10
Tex:	Austin[c]	P	4	3	0 (5)	0	5 (5)	2
	Dallas[c]	P	7	8	0 (5)	0	4 (5)	7
	Amarillo	R	4	4	0	0	0	2
	Corpus Christi	R	NS	4	NS	0	NS	2
	El Paso	R	NS	2	NS	0	NS	0
	Fort Worth	R	NS	6	NS	0	NS	7
	Harlingen	R	2	4	0	0	0	0
	Houston	R	NS	4	NS	0	NS	19
	Lubbock	R	NS	10	NS	0	NS	2
	Midland	R	NS	4	NS	0	NS	0
	San Antonio	R	NA	2	NA	0	NA	0
	Texarkana	R	8	11	0	0	15	18
	Uvalde	R	NS	2	NS	0	NS	0
	Wichita Falls	R	NS	9	NS	0	NS	2
Utah:	Salt Lake City[c]	P	2	5	0 (4)	0	11 (4)	11
Vt:	Burlington[c]	P	9	10	0 (5)	0	14 (5)	10
Va:	Norfolk[c]	P	8	11	0 (4)	0	8 (4)	10
Wash:	Seattle[c]	P	7	8	0 (4)	0	9 (4)	20
	Spokane[c]	P	5	6	0 (4)	0	2 (4)	8
	Benton County	R	NA		0	0	0	6
	Franklin County	R	NS		NS	0	NS	0
	Sandpoint, Idaho	R	NA		0	0	14	25
	Skagit County	R	NA		0	0	11	14
W.Va:	Charleston[c]	P	10	12	0 (3)	0	18 (3)	7
Wisc:	Milwaukee[c]	P	7	7	0 (4)	0	15 (4)	12
Wyo:	Laramie[c]	P	6	4	0 (4)	0	14 (4)	11
CANADA								
Alberta:	Calgary	P	8	8	(d)		13	18
	Edmonton	P	6	8	(d)		10	19
British Columbia:	Vancouver	P	10	14	(d)		16	46
Manitoba:	Winnipeg	P	9	8	(d)		27	25
New Brunswick:	Fredericton	P	12	15	(d)		17	23
Newfoundland:	St. Johns	P	13	20	(d)		20	40
Nova Scotia:	Halifax	P	6	11	(d)		14	22
Ontario:	Ft. William	P	14	16	(d)		29	32
	Ottawa	P	10	9	(d)		15	18
	Sault Ste. Marie	P	16	15	(d)		31	34

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for March 1969 and 12-month period, April 1968 through March 1969—Continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA—Continued								
Ontario:	Toronto	P	7	5	(d)		16	15
	Windsor	P	6	6	(d)		34	14
Quebec:	Montreal	P	5	9	(d)		17	21
	Quebec	P	8	12	(d)		21	29
Saskatchewan:	Regina	R	6	7	(d)		12	17
	Saskatoon	R	8	9	(d)		12	18
CENTRAL AND SOUTH AMERICA								
Columbia:	Bogota	P	NS	1	NS	0	0	0
Chile:	Santiago	P	0	0	0	0	0	0
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Montigo Bay	P	6	6	0	0	150	101
Venesuela:	Caracas	P	0	1	0	0	0	0
Canal Zone:	Cristobal[c]	P	3	2	0 (4)	1	11 (4)	13
Puerto Rico:	San Juan[c]	P	4	5	0 (5)	0	0 (5)	7
PMN network averages[f]			7	9	0	0	9	11

[a] P, pasteurized milk; R, raw milk.
[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.
[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.
[d] Radionuclide analysis not routinely performed.
[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS pasteurized milk network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

been omitted from table 3 since levels at the great majority of the stations were below the respective practical reporting levels. Table 4 gives monthly averages for those stations at which barium-140 was detected.

Table 4. Barium-140 in milk, March 1969

Sampling location	Radionuclide concentration (pCi/liter)
	Barium-140
Idaho: Idaho Falls (PMN)	1(4)
Mo.: Kansas City (PMN)	1(4)
Nebr.: Omaha	1(4)
Tenn.: Chattanooga	3(5)

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 19 pCi/liter in the United States for the month of March 1969 and the highest 12-month average was 20 pCi/liter (Little Rock, Ark., and Duluth, Minn.) representing 10.0 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 90 pCi/liter in the United States for the month of March 1969 and the highest 12-month average was 111 pCi/liter (Southeast Florida), representing 3.1 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level except Massena, N.Y. (State), 10 pCi/liter, 2 samples.

Acknowledgment

Appreciation is expressed to the personnel of the following health agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational, and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Division of Radiological Health
Bureau of Preventable Diseases
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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FOOD AND DIET SURVEILLANCE

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Last presented
California Diet Study	January–March 1968	October 1968
Connecticut Diet Study	January–June 1968	November 1968
Tri-City Diet, *HASL*	January–June 1968	April 1969

1. Radionuclides in Institutional Diet Samples October–December 1968

Bureau of Radiological Health and
Bureau of Community Environmental Management

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is administered by the Bureau of Radiological Health with the assistance of the Bureau of Community Environmental Management (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in 50 municipalities. These institutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of July 1965, 21 basic institutions and 8 auxiliary institutions distributed geographically as shown in figure 1, were being sampled. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys consumed 20 percent more food per day (*1,2*). Consequently, estimates for boys and/or girls can be calculated on the basis of the dietary intakes of children.

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week, (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drinking water, not included in the samples, is also sampled

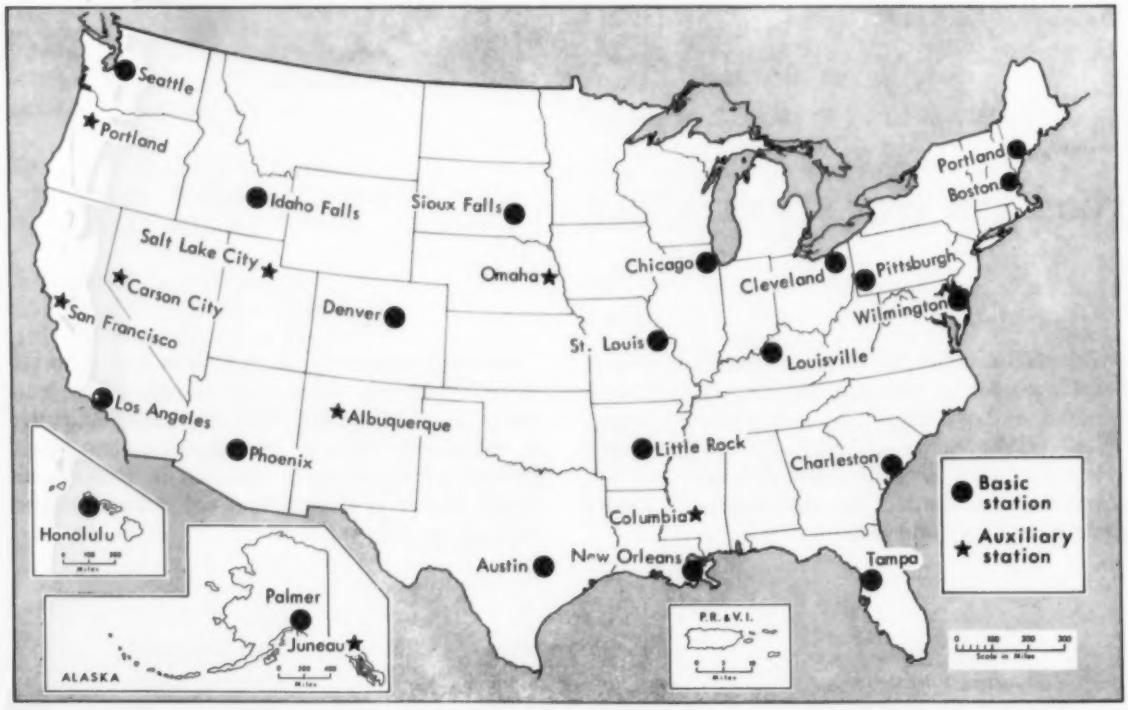

Figure 1. Institutional diet sampling locations as of October–December 1968

Table 1. Concentrations and intake of stable elements and radionuclides in Institutional total diets of children (9–12 years of age) October–December 1968

Location of Institution[a]	Month (1968)	Total weight (kg/day)	Calcium		Potassium		Strontium–89		Strontium–90		Iodine–131		Cesium–137		Barium–140		Radium–226	
			g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska: Palmer	Oct	1.89	0.60	1.13	1.4	2.6	0	0	8	15	0	0	13	25	0	0	0.5	0.9
	Nov	1.21	.77	.93	1.9	2.3	0	0	8	9	0	0	22	27	0	0	.8	1.0
	Dec	1.65	.60	.99	1.4	2.2	0	0	5	9	0	0	24	40	0	0	.3	.5
Ariz: Phoenix	Oct	2.17	.50	1.09	1.4	3.1	0	0	4	10	0	0	0	0	0	0	.6	1.3
	Nov	2.23	.72	1.61	1.2	2.7	0	0	5	10	0	0	0	0	0	0	.4	.9
	Dec	1.90	.46	.87	1.8	3.3	0	0	3	5	0	0	0	0	0	0	.6	1.1
Ark: Little Rock	Oct	1.53	.47	.72	1.3	2.0	NA	NA	5	8	0	0	0	0	0	0	.5	.8
	Nov	1.48	.47	.70	1.4	2.1	NA	NA	9	13	0	0	0	0	0	0	.4	.6
	Dec	1.60	.40	.64	1.2	2.0	NA	NA	5	9	0	0	0	0	0	0	.4	.6
Calif: Los Angeles	Oct[b]	1.84	.40	.74	1.2	2.3	0	0	5	8	0	0	0	0	0	0	.5	.9
	Nov[b]	1.18	.38	.45	1.4	1.6	0	0	6	0	0	0	0	0	0	0	.6	.7
	Dec[b]	1.77	.38	.67	1.3	2.3	0	0	3	5	0	0	0	0	0	0	.4	.7
Colo: Denver	Oct	2.42	.67	1.62	1.3	3.1	0	0	5	11	0	0	12	29	0	0	.5	1.2
	Nov	2.27	.72	1.63	1.6	3.7	0	0	5	12	0	0	16	36	0	0	.5	1.1
	Dec	2.19	.76	1.66	1.7	3.7	0	0	4	9	0	0	11	24	0	0	.4	.9
Del: Wilmington	Oct	2.16	.70	1.51	1.6	3.5	NA	NA	5	11	0	0	13	28	0	0	.8	1.7
	Nov	2.17	.68	1.48	1.6	3.5	NA	NA	8	17	0	0	0	0	0	0	.5	1.1
	Dec	2.18	.64	1.40	1.6	3.5	NA	NA	8	17	0	0	0	0	0	0	.5	1.1
Fla: Tampa	Oct[b]	1.40	.53	.74	1.7	2.3	NA	NA	10	14	0	0	38	53	0	0	.6	.8
	Nov[b]	1.38	.62	.86	1.8	2.5	NA	NA	10	13	0	0	37	51	0	0	.5	.7
	Dec[b]	1.32	.36	.48	1.3	1.7	NA	NA	6	8	0	0	24	32	0	0	.6	.8
Hawaii: Honolulu	Oct	2.38	.48	1.14	1.4	3.3	0	0	2	5	0	0	0	0	0	0	.4	1.0
	Nov	2.37	.40	.95	1.3	3.2	0	0	0	0	0	0	11	26	0	0	.3	.7
	Dec	2.14	.45	.96	1.5	3.2	0	0	3	6	0	0	16	34	0	0	.4	.9
Idaho: Idaho Falls	Oct[b]	1.80	1.37	2.47	1.6	2.9	0	0	9	16	0	0	16	29	0	0	.6	1.1
	Nov[b]	2.11	1.12	2.36	1.8	3.8	0	0	11	23	0	0	25	53	11	23	.5	1.1
	Dec[b]	2.02	1.25	2.53	1.8	3.6	0	0	8	16	14	28	23	46	15	30	.5	1.0
Ky: Louisville	Oct	1.65	.64	1.06	1.6	2.7	NA	NA	9	14	0	0	0	0	0	0	.7	1.2
	Nov	1.58	.68	1.07	1.7	2.7	NA	NA	8	12	0	0	0	0	0	0	.5	.8
	Dec	2.04	.69	1.41	1.6	3.2	NA	NA	12	24	0	0	11	22	0	0	.4	.8
La: New Orleans	Oct	1.76	.49	.86	1.5	2.6	0	0	9	16	0	0	18	32	0	0	.3	.5
	Nov	2.10	.55	1.16	1.6	3.3	0	0	9	18	0	0	12	25	0	0	.5	1.1
	Dec	1.94	.58	1.13	1.5	2.9	0	0	9	18	0	0	15	29	0	0	.4	.8
Maine: Portland	Oct	1.81	.91	1.65	1.7	3.1	NA	NA	11	20	0	0	16	29	19	29	.5	.9
	Nov	1.79	.67	1.20	1.8	3.2	NA	NA	8	14	0	0	20	36	0	0	.6	1.1
	Dec	1.69	.69	1.17	1.7	2.9	NA	NA	9	15	14	24	23	39	0	0	.7	1.2
Mass: Boston	Oct	2.15	.57	1.23	1.3	2.8	0	0	6	13	0	0	16	34	0	0	.3	.6
	Nov	2.30	.55	1.27	1.5	3.5	0	0	7	16	12	28	24	55	14	32	.4	.9
	Dec	2.21	.59	1.30	1.9	4.2	0	0	5	11	0	0	39	86	0	0	.3	.7
Mo: St. Louis	Oct	2.80	1.15	3.22	1.6	4.5	NA	NA	8	22	0	0	18	50	0	0	.8	2.2
	Nov	2.55	.89	2.27	2.0	5.1	NA	NA	7	18	0	0	0	0	0	0	.6	1.5
	Dec[b]	2.58	.91	2.35	1.8	4.6	NA	NA	9	23	0	0	19	49	0	0	.3	.8
Ohio: Cleveland	Oct	1.66	.66	1.10	1.7	2.8	NA	NA	7	12	0	0	0	0	0	0	1.1	1.8
	Nov	1.54	.58	.89	1.7	2.6	NA	NA	6	9	0	0	13	20	0	0	.6	.9
	Dec	1.72	.66	1.14	1.7	2.9	NA	NA	6	10	0	0	18	31	0	0	.6	1.0
Pa: Pittsburgh	Oct	2.34	.54	1.26	1.5	3.5	NA	NA	7	16	0	0	0	0	0	0	.9	2.1
	Nov	2.18	.52	1.13	1.3	2.8	NA	NA	7	15	0	0	12	26	0	0	.8	1.7
	Dec	2.12	.57	1.21	1.5	3.2	NA	NA	10	21	0	0	19	40	0	0	.3	.6
S.C.: Charleston	Oct[b]	1.77	.68	1.20	1.6	2.8	0	0	9	17	0	0	23	41	0	0	.4	.7
	Nov	1.20	.68	.82	1.5	1.8	0	0	11	13	0	0	22	26	0	0	.5	.6
	Dec	1.78	.81	1.44	1.5	2.6	0	0	10	17	0	0	17	30	0	0	.7	1.2
S. Dak: Sioux Falls	Oct[b]	1.67	.64	1.07	1.8	3.0	NA	NA	6	10	0	0	0	0	0	0	.8	1.3
	Nov[b]	1.78	1.12	1.99	1.5	2.7	NA	NA	8	14	12	21	17	30	13	23	2.1	3.7
	Dec[b]	1.48	.68	1.01	1.4	2.1	NA	NA	6	9	0	0	17	25	0	0	.7	1.0
Tex: Austin	Oct	1.68	.45	.76	1.6	2.7	NA	NA	2	4	0	0	0	0	0	0	.2	.3
	Nov	1.95	.80	1.56	1.6	3.1	NA	NA	5	10	0	0	0	0	0	0	.4	.8
	Dec[b]	1.81	.69	1.25	1.2	2.1	NA	NA	5	9	0	0	0	0	0	0	.3	.5
Wash: Seattle	Oct[b]	1.83	.56	1.02	1.8	3.3	0	0	8	14	0	0	20	37	0	0	.4	.7
	Nov[b]	2.06	.59	1.22	1.8	3.6	0	0	6	13	0	0	14	29	0	0	.4	.8
	Dec[b]	1.76	.50	.88	1.8	3.2	0	0	0	0	0	0	0	0	0	0	.5	.9
Institutional average	Oct	2.03	0.63	1.31	1.5	3.0	0	0	6	13	0	0	8	16	1	2	0.6	1.2
	Nov	1.93	0.65	1.24	1.6	3.0	0	0	7	13	1	2	10	19	1	2	0.5	1.0
	Dec	1.94	0.64	1.17	1.6	3.1	0	0	7	13	1	2	15	29	0	0	0.5	0.9

[a] Samples were not collected from the Chicago, Ill. area during this period due to difficulty of finding an appropriate institution.
[b] Since food samples were collected from two or more children who were not between the ages of 9 to 12, data for this month were not used in institutional average.

Table 2. Concentrations and intake of stable elements and radionuclides in Institutional total diets of individuals, October–December 1968[a]

Location of Institution	Month (1968)	Total weight (kg/day)	Calcium		Potassium		Strontium-89		Strontium-90		Cesium-137		Radium-226	
			g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska: Juneau	Oct	01.26	0.67	0.84	1.5	1.9	0	0	8	10	0	0	0.7	0.9
	Nov	1.24	.68	.84	1.9	2.3	0	0	13	16	14	17	.4	.5
	Dec	.97	.70	.68	1.7	1.6	0	0	11	11	19	18	.5	.5
Calif: San Francisco	Oct	2.41	.70	1.69	1.6	3.8	0	0	6	15	0	0	.4	1.0
	Nov	1.83	.89	1.63	1.5	2.8	6	11	5	9	11	20	.7	1.3
	Dec	2.45	.63	1.54	1.8	4.4	0	0	3	6	0	0	.3	.7
Miss: Columbia	Oct	2.15	.76	1.63	1.5	3.2	NA	NA	11	23	16	34	.5	1.1
	Nov	1.87	.85	1.59	1.6	3.0	NA	NA	9	17	0	0	.7	1.3
	Dec	2.35	.98	2.30	1.5	3.5	NA	NA	9	21	14	33	.5	1.2
Nebr: Omaha	Oct	2.24	1.11	2.49	2.0	4.5	NA	NA	8	18	0	0	1.0	2.2
	Nov	2.27	.96	2.18	1.7	3.9	NA	NA	8	18	14	32	1.2	2.7
	Dec	2.16	.76	1.64	1.8	3.9	NA	NA	6	13	18	39	.3	.6
Nev: Carson City	Oct	1.83	.75	1.37	1.8	3.3	0	0	4	7	12	22	.5	.9
	Nov	1.31	.79	1.03	1.7	2.2	0	0	5	7	12	16	.6	.8
	Dec	1.43	.77	1.10	2.1	2.9	0	0	2	3	12	17	.6	.9
N. Mex: Albuquerque	Oct	1.85	.51	.94	1.4	2.6	NA	NA	3	6	0	0	.3	.6
	Nov	2.49	.90	2.24	1.5	3.8	NA	NA	4	11	0	0	.4	1.0
	Dec	2.18	.86	1.87	1.7	3.7	NA	NA	4	8	0	0	.3	.7
Ore: Portland	Oct	2.24	.63	1.41	1.6	3.5	0	0	8	17	0	0	.7	1.6
	Nov	2.00	.66	1.32	1.9	3.7	0	0	5	11	17	34	.5	1.0
	Dec	2.13	.51	1.09	1.9	4.0	0	0	3	6	0	0	.6	1.3
Utah: Salt Lake City	Oct	2.08	.50	1.04	1.5	3.1	0	0	4	9	11	23	.5	1.0
	Nov	1.83	.75	1.37	1.2	2.1	0	0	3	5	11	20	.3	.5
	Dec	2.33	.58	1.35	1.6	3.7	0	0	5	10	14	33	.3	.7
Institutional average	Oct	2.01	0.70	1.42	1.6	3.2	0	0	6	13	5	10	0.6	1.2
	Nov	1.86	0.81	1.52	1.6	3.0	1	2	7	12	10	17	0.6	1.1
	Dec	2.00	0.72	1.44	1.7	3.5	0	0	5	10	10	17	0.4	0.8

[a] Iodine-131 and barium-140 had concentrations below the minimum detectable levels.

periodically. Each daily sample is kept frozen until the end of the collection period and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev; the Southeastern Radiological Health Laboratory, Montgomery, Ala; or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures was presented earlier (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from October through December 1968, for children 9 to 12 years of age. The stable elements, calcium and potassium, are reported in g/kg of diet, and the radionuclide concentrations of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes, in g/day or pCi/day, were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.93 kg/day compared to the network average of 1.86 kg/day observed from 1961 through 1967.

Strontium–90 dietary intake during this period averaged 7 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (*4*). Cesium–137 intakes averaged 11 pCi/day during this period. Strontium–89, barium–140, and iodine–131 concentrations were generally below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level will be reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2–standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Strontium–89	5 pCi/kg
Strontium–90	2 pCi/kg
Iodine–131	10 pCi/kg
Barium–140	10 pCi/kg
Cesium–137	10 pCi/kg
Radium–226	0.1 pCi/kg

Data from eight auxiliary stations are included in a separate table for general information. This is presented in table 2. These stations do not meet the criterion that the majority of the samples are collected from children who range in age from 9–12 years. In order to supplement the existing

environmental monitoring networks of the Bureau of Radiological Health, these eight institutions are being sampled in the same manner as the basic stations.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–March 1968	October 1968
April–June 1968	January 1969
July–September 1968	April 1969

REFERENCES

(1) ANDERSON, E. C., D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

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(3) PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1968. Radiol Health Data Rep 9:557–560 (October 1968).

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SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Last presented
California	July–December 1967	November 1968
Colorado River Basin	1967	December 1968
Drinking Water Analysis Program	1961–1966	August 1968
Florida	1965–1966	July 1968
Kansas	July–December 1967	November 1968
Minnesota	January–June 1968	February 1969
New York	January–June 1968	April 1969
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	January–June 1968	April 1969
Washington	July 1967–June 1968	June 1969

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States November-December 1968

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Water Pollution Surveillance System currently operated by the Federal Water Pollution Control Administration. Tables 1 and 2 present the current preliminary results of the alpha and beta radioanalyses for November and December 1968. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figures 1 and 2 indicate the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the November 1968 issue of *Radiological Health Data and Reports*.

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already

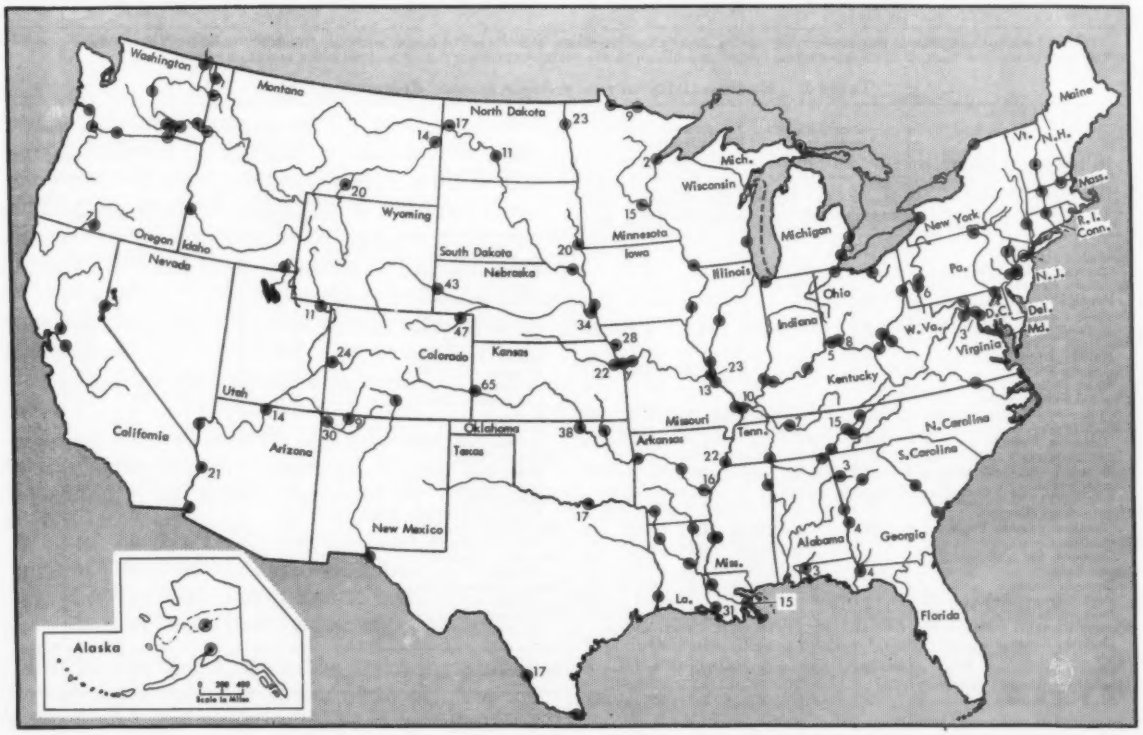

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, November 1968

Table 1. Radioactivity in raw surface waters, November 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex	0	2	2	1	8	9
Apalachicola River:						
Chattahoochee, Fla	0	0	0	1	3	4
Arkansas River:						
Coolidge, Kans	2	33	35	11	54	65
Ponca City, Okla	2	3	5	20	18	38
Pendleton Ferry, Ark	1	0	1	5	11	16
Atchafalaya River:						
Morgan City, La	4	1	5	21	10	31
Big Horn River:						
Hardin, Mont	0	7	7	2	18	20
Big Sioux River:						
Sioux Falls, S. Dak	<1	3	3	1	19	20
Chattahoochee River:						
Columbus, Ga	0	0	0	1	3	4
Clinch River:						
Kingston, Tenn[a]	0	0	0	3	12	15
Colorado River:						
Loma, Colo	1	8	9	6	18	24
Page, Ariz	0	5	5	<1	14	14
Parker Dam, Calif-Ariz	0	3	3	1	20	21
Coosa River:						
Rome, Ga	0	<1	<1	1	2	3
Cumberland River:						
Cheatham Lock, Tenn	0	0	0	2	5	7
Escambia River:						
Century, Fla	0	0	0	0	3	3
Great Lakes:						
Duluth, Minn	0	0	0	0	2	2
Green River:						
Dutch John, Utah	0	2	2	0	11	11
Kansas River:						
DeSoto, Kans	1	1	2	5	17	22
Klamath River:						
Keno, Ore	0	1	1	1	6	7
Little Miami River:						
Cincinnati, Ohio	0	0	0	0	8	8
Mississippi River:						
St. Paul, Minn	0	3	3	1	14	15
E. St. Louis, Ill	2	2	4	10	3	13
W. Memphis, Ark	1	1	2	9	13	22
New Orleans, La	1	1	2	2	13	15
Missouri River:						
Williston, N. Dak	1	3	4	3	14	17
Bismarck, N. Dak	0	4	4	1	10	11
St. Joseph, Mo	2	3	5	10	18	28
Missouri City, Mo	3	5	8	9	14	23
Monongahela River:						
Pittsburgh, Pa	0	0	0	0	6	6
North Platte River:						
Henry, Nebr	0	26	26	3	40	43
Ohio River:						
Cincinnati, Ohio	0	1	1	0	5	5
Cairo, Ill	1	0	1	2	8	10
Platte River:						
Plattsmouth, Nebr	4	6	10	8	26	34
Potomac River:						
Washington, D. C	0	0	0	0	3	3
Rainy River:						
International Falls, Minn	0	0	0	1	8	9
Red River, North:						
Grand Forks, N. Dak	0	2	2	2	21	23
Red River, South:						
Denison, Tex	0	0	0	0	17	17
Rio Grande:						
Laredo, Tex	2	4	6	6	11	17
San Juan River:						
Shiprock, N. Mex	11	2	13	19	11	30
South Platte River:						
Julesburg, Colo	1	29	30	10	37	47
Yellowstone River:						
Sidney, Mont	1	3	4	5	9	14
Maximum	11	33	35	21	54	65
Minimum	0	0	0	0	2	2

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

Table 2. Radioactivity in raw surface waters, December 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Apalachicola River:						
Chattahoochee, Fla	1	0	1	2	2	4
Arkansas River:						
Ponca City, Okla	4	3	7	18	17	35
Atchafalaya River:						
Morgan City, La	5	1	6	14	8	22
Big Horn River:						
Hardin, Mont	0	3	3	5	17	22
Big Sioux River:						
Sioux Falls, S. Dak	0	4	4	2	17	19
Chattahoochee River:						
Columbus, Ga	0	0	0	2	3	5
Clinch River:						
Kingston, Tenn[a]	0	0	0	1	17	18
Colorado River:						
Parker Dam, Calif-Ariz	0	5	5	0	15	15
Connecticut River:						
Wilder, Vt	0	0	0	1	3	4
Cumberland River:						
Cheatham Lock, Tenn	0	0	0	1	4	5
Escambia River:						
Century, Fla	0	0	0	2	2	4
Great Lakes:						
Duluth, Minn	0	0	0	2	0	2
Port Huron, Mich	0	0	0	1	4	5
Detroit, Mich	0	0	0	1	4	5
Kansas River:						
DeSoto, Kans	1	2	3	4	15	19
Little Miami River:						
Cincinnati, Ohio	0	2	2	0	6	6
Mississippi River:						
St. Paul, Minn	0	2	2	2	22	24
E. St. Louis, Ill	2	1	3	6	1	7
W. Memphis, Ark	4	0	4	11	8	19
New Orleans, La	4	1	5	13	8	21
Missouri River:						
Williston, N. Dak	0	1	1	5	19	24
Bismarck, N. Dak	0	2	2	2	14	16
St. Joseph, Mo	1	5	6	3	20	23
Kansas City, Kans	1	4	5	3	11	14
Missouri City, Mo	2	2	4	7	19	26
Ohio River:						
Cincinnati, Ohio	0	0	0	1	5	6
Cairo, Ill	1	0	1	7	7	14
Platte River:						
Plattsmouth, Nebr	<1	7	7	4	25	29
Potomac River:						
Great Falls, Md	0	1	1	3	5	8
Washington, D. C	0	0	0	1	4	5
Rainy River:						
International Falls, Minn	0	0	0	0	7	7
Red River, North:						
Grand Forks, N. Dak	0	0	0	2	22	24
Red River, South:						
Denison, Tex	0	1	1	0	17	17
South Platte River:						
Julesburg, Colo	2	35	37	12	73	85
Yellowstone River:						
Sidney, Mont	0	4	4	3	41	44
Maximum	5	35	37	18	73	85
Minimum	0	0	0	0	0	2

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

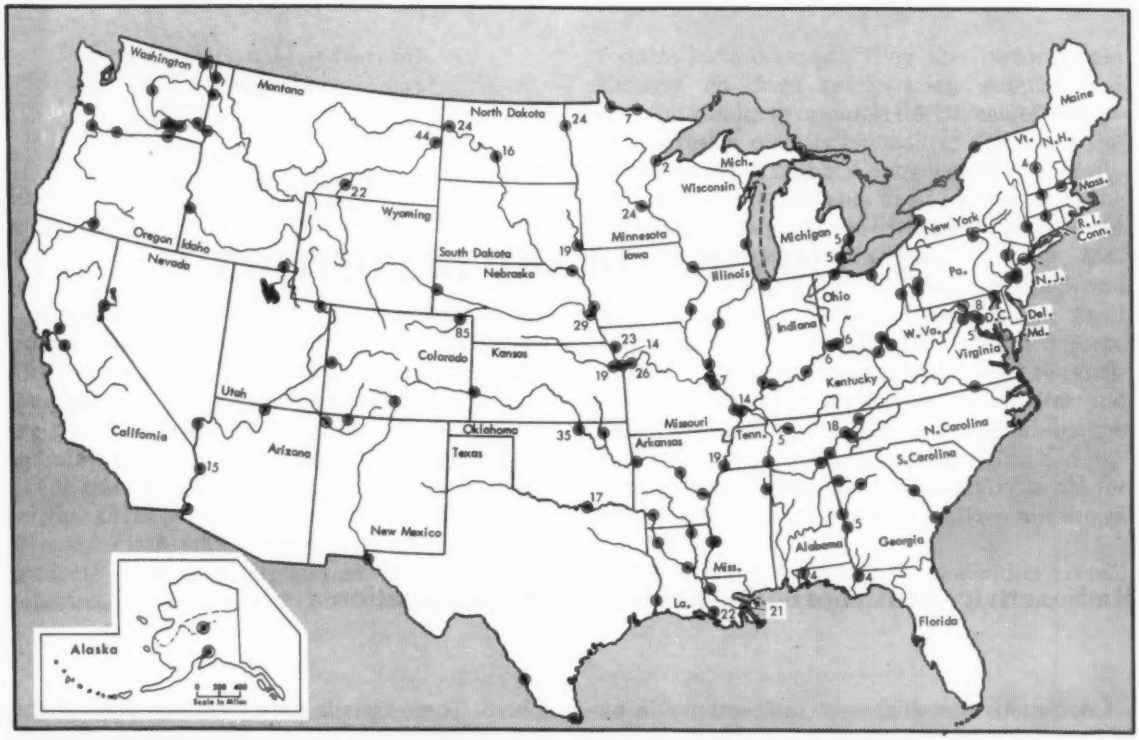

Figure 2. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, December 1968

provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. A discussion of gross radioactivity per gram of solids for all stations in the Water Pollution Surveillance System for 1961 through 1965 has been presented (*7*). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During November 1968, the following stations showed alpha values in excess of 15 pCi/liter on radioactivity for either suspended or dissolved solids:

Arkansas River; Coolidge, Kans.
North Platte River; Henry, Nebr.
South Platte River; Julesburg, Colo.

During December 1968, the following station showed alpha values in excess of 15 pCi/liter on radioactivity for either suspended or dissloved solids:

South Platte River; Julesburg, Colo.

None of the stations showed a gross beta radioactivity in excess of 150 pCi/liter during November and December 1968.

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(*1*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(*2*) *Ibid.*, 1959 Edition.
(*3*) *Ibid.*, 1960 Edition.
(*4*) *Ibid.*, 1961 Edition.
(*5*) *Ibid.*, 1962 Edition.
(*6*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(*7*) JULIAN, E. C. Gross radioactivity of the solids in selected surface waters of the United States, 1961–1965. Radiol Health Data Rep 9:1–15 (January 1968).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*.

Network	Period	Issue
HASL Fallout Network	July–December 1967	September 1968
HASL 80th Meridian Network	Calendar Year 1966	December 1968
Plutonium in Airborne Particulates	January–March 1968	January 1969

1. Radiation Alert Network March 1969

Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during March 1969. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, March 1969

Station location		Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Number of samples	Precipitation			
								Total depth (mm)	Field estimation of deposition		
		Air	Maximum	Minimum	Average [a]				Number of samples	Depth (mm)	Total deposition (nCi/m³)
Ala:	Montgomery	20	3	0	1	Sept 68	5	134	5	134	0
Alaska:	Adak	7	2	1	2	Apr 68	[c]				
	Anchorage	6	0	0	0	Oct 68	[c]				
	Attu Island	16	0	0	0	Mar 69	[c]				
	Fairbanks	[b]				Nov 68	[c]				
	Juneau	19	0	0	0	Dec 68	13	222	13	222	0
	Kodiak	[b]				Jan 69	[c]				
	Nome	[b]				May 69	[c]				
	Point Barrow	29	0	0	0	Apr 69	[c]				
	St. Paul Island	1	1	1	1	June 69	[c]				
Ariz:	Phoenix	21	10	1	5	Dec 68	[c]				
Ark:	Little Rock	11	3	0	1	Oct 68	[c]				
Calif:	Berkeley	21	1	0	0	Jan 69	5	35	5	35	0
	Los Angeles	20	1	0	1	May 69	[c]				
C.Z:	Ancon	16	0	0	0	Jan 69	[c]				
Colo:	Denver	20	7	0	2	Jan 69	4	23	[d]		
Conn:	Hartford	20	0	0	0	Nov 68	4	43	4	43	0
Del:	Dover	21	1	0	0	July 69	[c]				
D.C:	Washington	9	1	0	0	Apr 69	[c]				
Fla:	Jacksonville	21	1	0	0	Oct 68	6	116	6	116	80
	Miami	16	1	0	0	Nov 68	4	40	4	40	0
Ga:	Atlanta	21	1	1	1	June 69	1	43	1	43	30
Guam:	Agana	[b]				July 69	[c]				
Hawaii:	Honolulu	30	2	0	0	Mar 69	1	50	[d]		
Idaho:	Boise	22	4	0	1	Mar 69	4	11	4	11	0
Ill:	Springfield	19	2	0	1	Apr 69	[c]				
Ind:	Indianapolis	20	4	0	1	June 69	5	24	5	24	29
Iowa:	Iowa City	18	1	0	0	Jan 69	4	29	4	29	0
Kans:	Topeka	20	2	0	0	Oct 68	2	25	2	25	2
Ky:	Frankfort	12	4	1	1	Apr 69	[c]				
La:	New Orleans	20	1	0	0	Apr 69	7	207	[d]		
Maine:	Augusta	19	0	0	0	May 69	11	48	11	48	0
Md:	Baltimore	19	1	0	0	Nov 68	3	30	3	30	12
	Rockville	10	1	0	0	Mar 69	[c]				
Mass:	Lawrence	19	0	0	0	July 69	3	45	3	45	23
	Winchester	19	0	0	0	Feb 69	5	52	5	52	0
Mich:	Lansing	13	4	0	1	Mar 69	[c]				
Minn:	Minneapolis	21	0	0	0	July 69	3	24	3	24	9
Miss:	Jackson	19	1	0	0	May 69	4	158	4	158	41
Mo:	Jefferson City	20	2	0	0	June 69	3	39	3	39	0
Mont:	Helena	19	2	0	1	Feb 69	2	2	2	2	3
Nebr:	Lincoln	19	1	0	0	June 69	2	25	2	25	8
Nev:	Las Vegas	16	2	0	1	Nov 68	[c]				
N.H:	Concord	20	0	0	0	Apr 69	[c]				
N.J:	Trenton	21	1	0	0	May 69	4	49	4	49	22
N. Mex:	Santa Fe	13	2	0	1	Feb 69	3	8	3	8	10
N.Y:	Albany	12	2	0	1	June 69	3	34	3	34	78
	Buffalo	19	1	0	0	Jan 69	[c]				
	New York City	21	0	0	0	Feb 69	[c]				
N.C:	Gastonia	16	11	1	3	Jan 69	2	60	[d]		
N.Dak:	Bismarck	21	0	0	0	Apr 69	3	3	3	3	0
Ohio:	Cincinnati	[b]				July 69	[c]				
	Columbus	17	6	0	1	May 69	2	22	0	0	[e]
	Painesville	20	1	0	1	Nov 68	6	7	6	7	6
Okla:	Oklahoma City	19	1	0	0	Mar 69	2	54	2	54	0
	Ponca City	20	2	0	1	Nov 68	3	38	3	38	0
Ore:	Portland	18	2	0	1	June 69	3	15	3	15	1
Pa:	Harrisburg	13	1	0	0	June 69	[c]				
P.R:	San Juan	[b]				May 69	[c]				
R.I:	Providence	18	0	0	0	Mar 69	[c]				
S.C:	Columbia	17	1	0	0	Feb 69	5	90	5	90	24
S. Dak:	Pierre	8	2	0	0	Dec 68	[c]				
Tenn:	Nashville	[b]				Mar 69	[c]				
Tex:	Austin	20	6	1	2	July 69	5	46	[d]		
	El Paso	13	5	1	2	Apr 69	[c]				
Utah:	Salt Lake City	31	2	0	1	May 69	5	48	3	7	1
Vt:	Barre	18	1	0	0	Oct 68	5	36	5	36	0
Va:	Richmond	20	1	0	0	Oct 68	6	72	6	72	32
Wash:	Seattle	24	2	0	0	Oct 68	2	18	[d]		
	Spokane	21	2	0	0	July 69	[c]				
W. Va:	Charleston	17	3	0	1	Feb 69	6	27	6	27	3
Wisc:	Madison	21	1	0	0	Oct 68	6	33	6	33	24
Wyo:	Cheyenne	20	3	0	1	Nov 68	2	7	2	7	13
Network summary		1,187	11	0	1		4	50	4	46	13

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

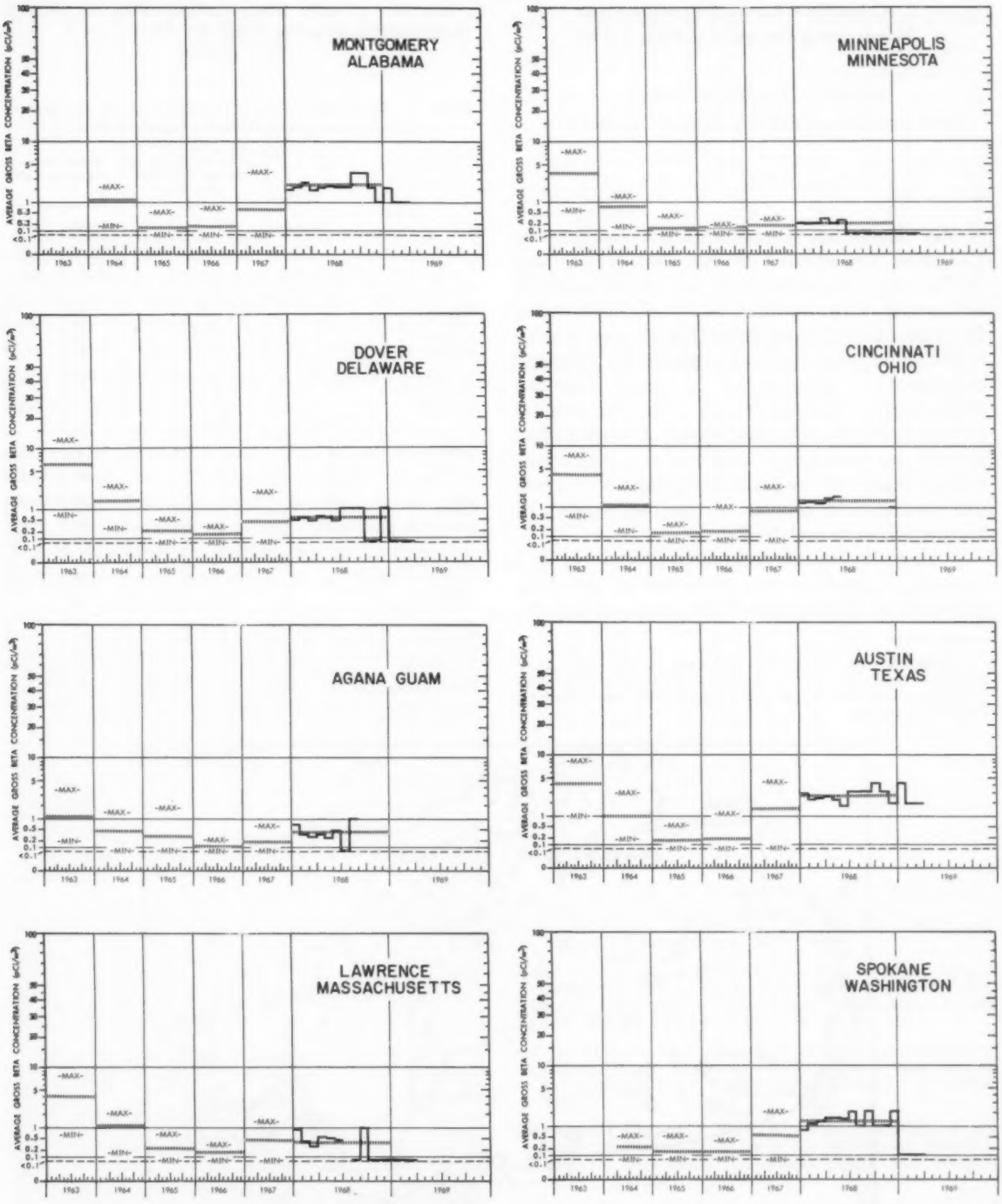

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1963-March 1969

2. Canadian Air and Precipitation Monitoring Program[1], March 1969

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the June 1969 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data in the April 1969 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for March 1969 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, March 1969

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	5	0.1	0.1	0.1	30	1.0
Coral Harbour	30	.1	.0	.0	27	.2
Edmonton	31	.2	.1	.1	63	.5
Ft. Churchill	31	.1	.0	.1	26	.2
Ft. William	17	.1	.1	.1	183	1.5
Fredericton	31	.2	.0	.1	16	.7
Goose Bay	31	.1	.0	.1	42	3.1
Halifax	31	.2	.0	.1	50	3.0
Inuvik	31	.1	.0	.1	48	.5
Montreal	31	.1	.0	.1	24	1.1
Moosonee	30	.2	.0	.1	NS	NS
Ottawa	31	.1	.0	.1	20	1.0
Quebec	31	.1	.0	.1	16	1.3
Regina	30	.1	.0	.1	27	.4
Resolute	29	.2	.0	.1	45	.2
St. John's, Nfld	29	.1	.0	.1	15	2.6
Saskatoon	31	.1	.0	.1	42	.3
Saulte Ste Marie	31	.1	.0	.1	29	1.1
Toronto	31	.2	.0	.1	39	1.2
Vancouver	31	.2	.0	.1	28	2.4
Whitehorse	31	.1	.0	.1	28	.3
Windsor	31	.1	.0	.1	27	1.4
Winnipeg	31	.2	.1	.1	32	.3
Yellowknife	31	.1	.1	.1	53	.3
Network summary	697	0.2	0.0	0.1	40	1.1

NS, no sample.

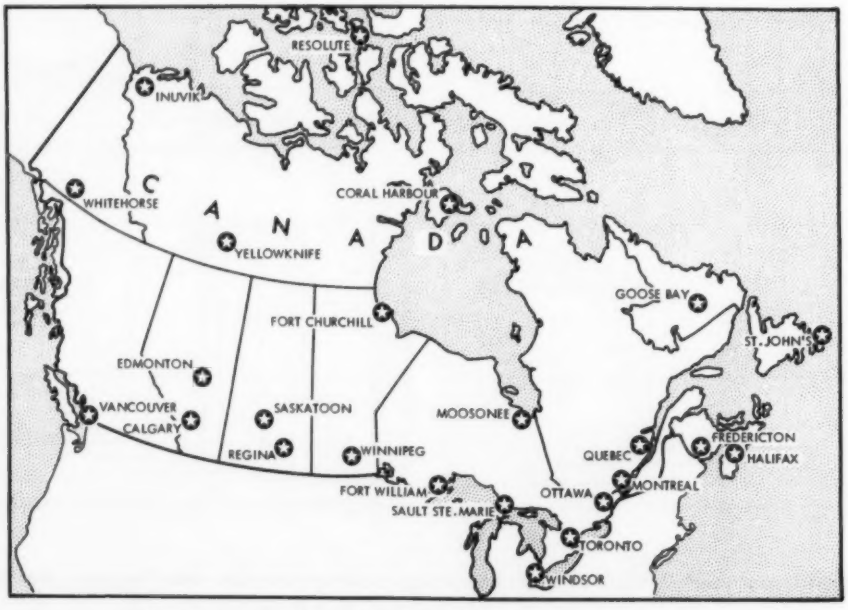

Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program March 1969

Pan American Health Organization and
U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. It should be noted that a new sampling station has been established in Quito, Ecuador. Analytical techniques were described in the January 1968 *Radiological Health Data and Reports*. The March 1969 air monitoring results from the participating countries are given in table 3.

Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, March 1969

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	15	0.30	0.11	0.19
Bolivia: La Paz	3	.02	.01	.01
Chile: Santiago	30	.56	.02	.19
Colombia: Bogata	11	.04	.01	.02
Ecuador: Guayaquil	21	.06	.01	.04
Quito	18	.19	.00	.01
Guyana: Georgetown	18	.10	.00	.06
Jamaica: Kingston	1	.06	.06	.06
Peru: Lima	NS			
Venezuela: Caracas	12	.09	.02	.06
West Indies: Trinidad	20	.25	.02	.09
Pan American summary	149	0.56	0.00	0.09

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

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(4) BEALE, J. and J. GORDON. The Operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, April-June 1968[1]

Bureau of Radiological Health
U.S. Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older age groups have shown their bone strontium–90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

Laboratory procedures

The bones are analyzed at Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium–90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium–90 content is then calculated (*3*) from the yttrium–90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy, synthetic "bone ash" samples (calcium phosphate spiked with strontium–90) are analyzed periodically and crosscheck analyses are carried out quarterly with the Health and Safety Laboratory

[1] Period during which death or surgical procedure occurred.

Figure 1. Geographical regions for human bone sampling

Table 1. Strontium-90 in human bone, April–June 1968

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Northeast:						
N. Y	V	1	M	71.7 ± 11.0[c]	24.1	2.97
N. J	V	3	M	91.9 ± 8.9	32.7	2.81
N. Y	V	3	M	53.4 ± 6.8	19.7	2.71
Pa	V	8	M	31.4 ± 4.0	19.1	1.64
	V	8	F	64.1 ± 6.9	32.8	1.95
N. Y	V	9	M	46.9 ± 8.8	30.1	1.55
Pa	V	11	M	59.1 ± 7.2	35.6	1.66
Mass	V	12	M	110.0 ± 8.0	40.0	2.75
N. J	V	13	M	91.1 ± 7.4	36.8	2.47
Vt	V	15	M	90.4 ± 7.3	40.8	2.21
Mass	V	16	M	116.0 ± 12.0	46.7	2.48
Vt	V	18	M	167.0 ± 16.0	54.5	3.06
	V	19	M	119.0 ± 10.0	58.3	2.04
N. J	V	20	F	93.3 ± 10.0	34.3	2.72
Mass	V	20	M	173.0 ± 12.0	55.5	3.11
	V	20	M	152.0 ± 12.0	67.7	2.24
	V	21	M	108.0 ± 9.3	52.5	2.05
Vt	V	21	M	115.0 ± 10.0	48.5	2.37
N. Y	V	21	M	175.0 ± 12.0	48.8	3.58
Mass	V	23	M	86.0 ± 8.0	42.2	2.03
N. Y	V	23	F	76.3 ± 7.5	46.8	1.63
Mass	V	24	F	85.5 ± 12.0	60.7	1.40
N. Y	V	25	M	76.2 ± 8.2	52.0	1.46
Southeast:						
S. C	V	2	F	174.0 ± 12.0	30.7	5.66
Md	V	3	F	71.9 ± 13.0	28.6	2.51
	V	3	M	79.7 ± 8.9	34.6	2.30
	V	4	M	97.2 ± 8.8	30.8	3.15
S. C	V	4	M	97.4 ± 9.4	27.4	3.55
Md	V	5	F	75.0 ± 7.0	27.3	2.74
S. C	V	5	F	77.2 ± 8.7	28.1	2.74
Md	V	9	F	129.0 ± 9.1	32.0	4.03
Ga	V	10	F	108.0 ± 10.0	30.6	3.52
Md	V	11	F	146.0 ± 12.0	47.3	3.08
	V	11	F	57.8 ± 7.7	31.5	1.83
	V	12	M	94.7 ± 8.8	36.6	2.58
	V	13	F	135.0 ± 13.0	50.5	2.67
	V	13	M	170.0 ± 12.0	45.8	3.71
S. C	V	13	M	47.0 ± 5.2	40.4	1.16
Md	V	14	F	263.0 ± 17.0	68.9	3.81
	V	14	M	84.9 ± 10.0	44.2	1.92
	V	14	F	149.0 ± 11.0	56.2	2.65
	V	14	M	114.0 ± 10.0	43.9	2.59
	V	16	M	69.1 ± 8.0	47.9	1.44
N. C	V	16	F	81.5 ± 8.5	38.8	2.10
	V	16	F	158.0 ± 9.7	42.6	3.70
Md	V	17	M	115.0 ± 10.0	57.7	1.99
	V	17	M	104.0 ± 11.0	44.1	2.35
	V	17	M	170.0 ± 11.0	58.6	2.90
	V	17	M	202.0 ± 14.0	61.1	3.30
	V	17	M	151.0 ± 12.0	49.3	3.06
N. C	V	17	M	74.9 ± 6.8	43.0	1.74
Md	V	18	M	157.0 ± 14.0	52.2	3.00
N. C	V	19	M	223.0 ± 13.0	51.2	4.35
S. C	V	19	M	126.0 ± 12.0	49.8	2.53
Md	V	20	M	132.0 ± 13.0	61.4	2.14
S. C	V	20	F	103.0 ± 9.2	59.3	1.73
Md	V	21	M	72.1 ± 6.5	40.5	1.78
	V	21	M	89.8 ± 9.6	55.5	1.61
	V	21	M	198.0 ± 15.0	60.4	3.27
	V	21	M	109.0 ± 9.3	47.3	2.30
	V	22	M	112.0 ± 14.0	62.7	1.78
Tenn	V	22	M	93.8 ± 11.0	48.5	1.93
Md	V	22	M	110.0 ± 10.0	65.9	1.66
	V	22	M	143.0 ± 10.0	50.1	2.85
	V	22	M	84.5 ± 11.0	57.8	1.46
N. C	V	22	M	114.0 ± 11.0	55.6	2.05
Md	V	23	M	84.9 ± 9.9	47.3	1.79
	V	23	F	91.9 ± 12.0	71.4	1.28
	V	23	M	132.0 ± 13.0	54.2	2.43
	V	23	M	96.6 ± 11.0	49.0	1.97
N. C	V	23	F	72.8 ± 7.4	41.0	1.77
Md	V	24	M	94.9 ± 8.1	49.1	1.93
Tenn	V	24	M	69.3 ± 7.7	52.9	1.31
Md	V	25	M	119.0 ± 9.7	49.6	2.39
	V	25	M	83.8 ± 8.6	52.2	1.60
S. C	V	25	M	127.0 ± 11.0	61.4	2.06
	V	25	M	104.0 ± 9.9	44.1	2.35
Central:						
Wisc	V	1	F	69.7 ± 7.9	25.2	2.76
	V	2	F	67.9 ± 8.5	29.6	2.29
Ind	V	3	M	143.0 ± 11.0	35.9	3.98
Wisc	V	4	F	65.8 ± 7.8	26.6	2.47
Ohio	V	4	M	125.0 ± 11.0	50.8	2.46
Wisc	V	4	M	129.0 ± 9.8	24.6	5.24
Minn	V	4	F	101.8 ± 8.7	24.7	4.12
Wisc	V	6	F	76.9 ± 10.0	33.3	2.30
	V	7	M	96.0 ± 8.9	33.4	2.87

See footnotes at end of table.

Table 1. Strontium-90 in human bone, April–June 1968—Continued

Bone region and State	Bone type [a]	Age [b] (years)	Sex	Strontium-90 concentration (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Central:						
Minn.	V	8	F	68.0 ± 6.8	27.7	2.45
Ohio	V	11	M	119.0 ± 8.2	32.4	3.67
	V	11	M	129.0 ± 17.0	67.8	1.90
Mich.	V	12	F	102.0 ± 11.0	42.3	2.41
Ohio	V	12	M	113.0 ± 10.0	56.5	2.00
	V	12	F	118.0 ± 13.0	56.2	2.09
	V	13	M	133.0 ± 13.0	64.7	2.05
Ill.	V	13	M	83.2 ± 7.9	38.8	2.14
Ohio	V	16	M	134.0 ± 9.6	54.2	2.47
	V	16	F	139.0 ± 12.0	61.9	2.24
	V	17	M	214.0 ± 17.0	71.5	2.99
Minn.	V	17	M	112.0 ± 11.0	51.0	2.19
Mich.	V	18	F	244.0 ± 19.0	62.1	3.92
Ohio	V	18	M	160.0 ± 12.0	69.8	2.29
Mich.	V	19	F	202.0 ± 12.0	50.0	4.04
	V	20	M	145.0 ± 14.0	44.4	3.26
Ohio	V	20	F	113.0 ± 14.0	59.1	1.91
	V	20	M	113.0 ± 12.0	55.4	2.03
Wisc.	V	22	M	94.8 ± 8.7	44.5	2.13
Ohio	V	24	M	44.7 ± 5.4	29.3	1.52
	V	24	F	71.3 ± 9.9	58.9	1.21
Northwest:						
Ore.	V, SK	0	M	99.2 ± 8.1	37.5	2.64
	V	10	M	50.0 ± 6.5	37.8	1.32
	V	14	M	51.4 ± 5.9	34.4	1.49
	V	16	M	125.0 ± 13.0	53.2	2.34
	V	17	M	158.0 ± 12.0	47.3	3.34
	V	18	M	114.0 ± 12.0	52.5	2.17
	V	20	M	93.3 ± 12.0	60.3	1.54
	V	21	F	72.5 ± 10.0	48.9	1.48
Ohio	V	25	M	61.2 ± 7.0	48.7	1.25
Southwest:						
Tex.	V	0	F	325.0 ± 22.0	32.3	10.06
Colo.	V	10	F	111.0 ± 11.0	48.6	2.28
	V	12	M	80.6 ± 7.0	33.0	2.44
	V	16	M	133.0 ± 13.0	47.0	2.82
	V	16	F	90.8 ± 9.3	48.6	1.86
	V	17	M	99.4 ± 10.0	49.8	1.99
	V	17	M	70.6 ± 8.5	44.6	1.58
	V	17	M	83.5 ± 9.5	51.7	1.61
	V	17	M	114.0 ± 11.0	54.9	2.07
	V	17	M	118.0 ± 9.8	47.7	2.47
	V	18	M	127.0 ± 10.0	47.3	2.68
	V	18	M	149.0 ± 15.0	56.0	2.66
	V	19	F	99.1 ± 9.7	53.9	1.83
	V	19	M	77.2 ± 8.9	40.5	1.90
	V	20	M	53.0 ± 9.5	51.1	1.03
	V	20	M	90.4 ± 8.6	54.6	1.65
	V	21	M	97.4 ± 8.5	51.2	1.90
	V	21	M	107.0 ± 10.0	55.3	1.93
Calif.	V	21	M	71.2 ± 7.4	49.7	1.43
Colo.	V	24	M	57.6 ± 6.5	44.6	1.29
North:						
Alaska	R	13	F	476.0 ± 50.0	116.0	4.10

[a] Type of bone: vertebrae, V; rib, R; skull, SK.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

of the AEC, which performs similar analyses.

The analytical results for strontium–90 in individual bones from persons dying during the second quarter (April–June) of 1968 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium–90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–5*).

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Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
October–December 1967	February 1969
January–March 1968	April 1969

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Atomics International, and the Paducah Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International[2] July–December 1968

North American Rockwell Corporation
Canoga Park, California

Atomics International, a division of North American Rockwell Corporation, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants for medical, industrial, and scientific applications.

[2] Summarized from "Environmental Monitoring, Semiannual Report, July 1 to December 31, 1968" Atomics International, Division of North American Rockwell Corporation.

The company headquarters is located in Canoga Park, California, approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check

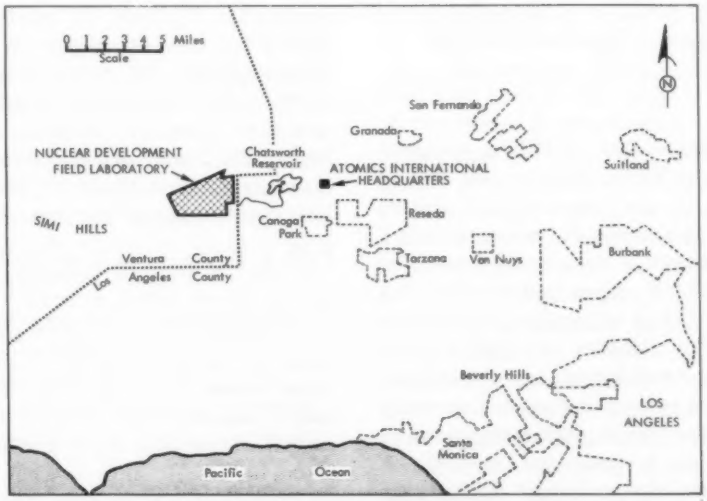

Figure 1. Atomics International facilities and vicinity

on the effectiveness of radiological safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV–70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20-cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for July–December 1968.

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics Intl., July–December 1968

Location	July–December 1968	
	Number of samples	Average concentration (pCi/m³)
Headquarters	349	0.18
NDFL	1,095	.17

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 2.

Water samples are also collected monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 3.

Table 2. Well water radioactivity, NDFL site July–December 1968

Type of radioactivity	July–December 1968	
	Number of samples	Average concentration (pCi/m³)
Alpha	12	0.14
Beta-gamma	12	5.1

Table 3. Chatsworth Reservoir water radioactivity Atomics Intl., July–December 1968

Sample	Type of radioactivity	July–December 1968	
		Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	6	0.22
	Beta-gamma	6	6.2
Supply surface	Alpha	6	.30
	Beta-gamma	6	4.9

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NDFL Boundary. Samples, obtained and analyzed monthly, include stream bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 4. Radioactivity in the Rocketdyne reservoir and Bell Creek[a], July–December 1968

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir station 6[a] (pCi/liter)	5	0.19	9.3
Reservoir station 12[a] (pCi/liter)	6	.08	7.1
Bell Creek mud (pCi/g)	6	.33	25
Bell Creek vegetation (pCi/g ash)	6	.42	169
Bell Creek water (pCi/liter)	3	.03	5.2

[a] Location not shown on on figure 1.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Table 5. Radioactivity in the soil, Atomics Intl. July–December 1968

Area	Type of radioactivity	July–December 1968	
		Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.46
	Beta-gamma	72	27
Offsite	Alpha	24	.47
	Beta-gamma	24	26

Vegetation samples obtained in the field are of the same plant type wherever possible, generally, sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 6. Radioactivity in vegetation, Atomics Intl. July–December 1968

Area	Type of radioactivity	July–December 1968	
		Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.47
	Beta-gamma	72	139
Offsite	Alpha	24	.46
	Beta-gamma	24	138

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
July–December 1967	June 1968
January-June 1968	December 1968

2. Paducah Plant[3] July–December 1968

Union Carbide Corporation
Paducah, Kentucky

The Paducah Plant is a government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant, a former source of diffusion plant feed, was placed on standby in June of 1964 and was reactivated in August 1968. Parts of the associated uranium metal foundry, usually on standby, are operated infrequently as the need arises. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium–234, and protactinium–234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probable biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

Because of the necessity for health protection in process areas, the high intrinsic value of uranium, and the desire to maintain a wholesome relationship with neighboring communities and individuals, the Paducah Plant provides confinement and recovery systems at the plant. The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this

[3] Summarized from "Environmental Concentrations of Radioactive Materials Near the Paducah Plant—Report for the Second Half of 1968."

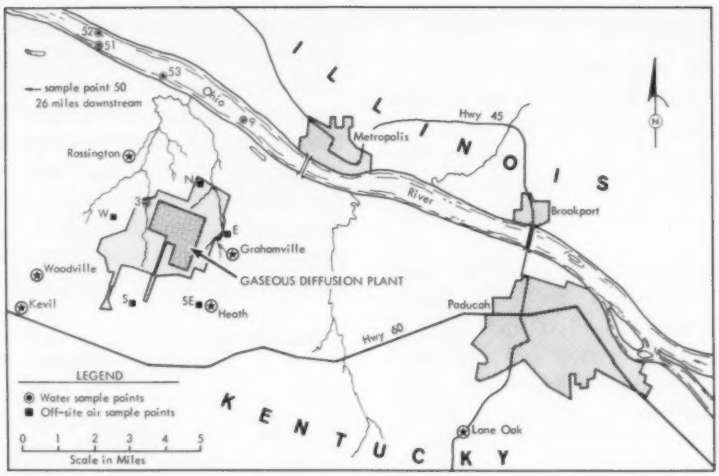

Figure 2. Sampling locations, Paducah Gaseous Diffusion Plant

fence (figure 2). Big Bayou Creek water is sampled continuously, and grab samples are collected at five locations in the Ohio River. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger–Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant work environment of employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual.

The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that it is improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radioactivity in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radionuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 7 through 10.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch

Table 7. Uranium concentrations in outdoor air samples, Paducah Plant, July–December 1968

Sample location[a]	Number of samples	Uranium alpha radioactivity[b] (pCi/m³)		
		Maximum	Minimum[c]	Mean[d]
At plant perimeter fence:				
North	27	0.24	<0.02	0.06
East	27	.13	< .02	.04
South	27	.06	< .02	.01
West	27	.05	< .02	.01
Total	108	0.24	<0.02	0.03
About 1 mile outside plant perimeter fence:				
North	27	.06	< .02	.01
East	27	.06	< .02	.01
South	27	.09	< .02	.01
West	27	.06	< .02	.01
Southeast	27	.06	< .02	.01
Total	135	0.09	<0.02	0.01

[a] See figure 2.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha dis/sec.
[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.
[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

Table 8. Beta radioactivity in outdoor air samples, Paducah Plant, July–December 1968

Sample location[a]	Number of samples	Beta radioactivity (pCi/m³)		
		Maximum	Minimum[b]	Mean[c]
At plant perimeter fence:				
North	27	5.9	<0.01	1.7
East	27	6.3	< .01	1.2
South	27	.4	< .01	.1
West	27	.5	< .01	.2
Total	108	6.3	<0.01	0.8
About 1 mile outside plant perimeter fence:				
North	27	.68	< .01	.19
East	27	.26	< .01	.15
South	27	.40	< .01	.14
West	27	.31	< .01	.13
Southeast	27	.41	< .01	.15
Total	135	0.68	<0.01	0.15

[a] See figure 2.
[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m³.
[c] The AEC standard, applicable to this table is 1×10^3 pCi/m³, which is the concentration limit of thorium–234, the daughter product of uranium–238. Insignificant amounts of other daughters are present in freshly refined uranium.

diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

The average alpha-particle count—interpreted as uranium, the most likely source of radioactivity—of the 108 and the 135 air samples collected during the second half of 1968 at the perimeter fence and 1 mile, respectively, were 1.5 percent and 0.5 percent of the AEC standard set for individuals residing in the vicinity of a controlled area. The average beta-particle count of these samples was 0.08 percent of the standard at the perimeter fence and 0.02 percent of the standard at 1 mile.

Table 9. Concentrations of uranium in water Paducah Plant, July–December 1968

Sample location[a]	Number of samples	Uranium[b] (pCi/liter)		
		Maximum	Minimum[c]	Mean[d]
Big Bayou Creek 3	27	9	<1	4
Ohio River 9	6	<1	<1	<1
Composite of 50, 51, 52, and 53	6	<1	<1	<1

[a] See figure 2.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha dis/sec.
[c] The minimum detectable uranium in water is 1 pCi/liter.
[d] The AEC standard for natural uranium in water beyond a controlled area is 2×10^4 pCi/liter.

Table 10. Concentration of beta-particle emitters in water, Paducah Plant, July–December 1968

Sample location[a]	Number of samples	Beta-particle emitters (pCi/liter)		
		Maximum	Minimum[b]	Mean[c]
Big Bayou Creek 3	27	300	<100	<100
Ohio River 9	6	100	<100	100
Composite of 50, 51, 52, and 53	6	100	<100	<100

[a] See figure 2.
[b] The minimum detectable amount of beta-particle emitters in water is 100 pCi/liter.
[c] The AEC standard for the immediate daughter products of uranium in water released to the environs is 2×10^4 pCi/liter.

The average uranium analyses of weekly water samples collected continuously from the Big Bayou Creek during July–December 1968 was 0.02 percent of the AEC standard for water beyond a controlled area. The results of the uranium analyses for each of the 12 grab samples collected at monthly intervals from the Ohio River below the plant were less than 0.01 percent of the AEC standard.

The concentration of beta-particle emitters in the Big Bayou Creek averaged less than 0.5 percent of the AEC standard for the decay products of uranium–238. The beta radioactivity of the Ohio River was less than 0.5 percent of the standard for uranium–238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/hr at all sampling stations for July–December 1968.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
July–December 1967	May 1968
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Reported Nuclear Detonations, June 1969

The U.S. Atomic Energy Commission announced a nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted underground by the Atomic Energy Commission at is Nevada Test Site on June 12, 1969.

Errata

In the article "Radioactivity in North Carolina Surface, Ground, and Cistern Waters, January–December 1967" which appeared in the May 1969 issue of *Radiological Health Data and Reports*, the last sentence in the first column of page 214 should read: "If gross beta radioactivity above 5 pCi/liter is detected in a ground water sample, it is analyzed by gamma-ray spectroscopy *and* for radium."

In the Mound Laboratory article on page 233 of the May 1969 issue of *Radiological Health Data and Reports* there is an error in the units of tables 7 and 8. The columns titled "concentration" in table 7 should have units of "fCi/m^3." The same column in table 8 should have units of "nCi/m^3."

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

STUDIES OF CHEMICAL AND RADIOCHEMICAL COMPOSITION OF NATURAL GAS FROM THE CAVITY PRODUCED BY THE PROJECT GASBUGGY NUCLEAR SHOT. *C. F. Smith* and *F. F. Momyer. Radiological Health Data and Reports, Vol. 10, July 1969*, pp. 281–288.

Data relating to the chemical and radiochemical results from Project Gasbuggy chimney-gas samples obtained prior to 210 days after detonation (December 10, 1967) are presented for significant nonradioactive components of the gas and for tritium and krypton-85. A discussion of changes in composition occurring during the flaring of 5×10^7 ft^3 gas in the late spring of 1968 is included. Some interpretation of the observed changes is advanced but with the data now available, no definitive conclusions seem warranted. This is a status report of the continuing effort to define and understand the chemical and radiochemical aspects of Project Gasbuggy.

Keywords: Chemical, chimney-gas, Gasbuggy Project, tritium, krypton-85, natural gas.

RADIOECOLOGICAL SURVEILLANCE OF THE WATERWAYS AROUND A NUCLEAR FUELS REPROCESSING PLANT. *N. I. Sax, P. C. Lemon, A. H. Benton,* and *J. J. Gabay. Radiological Health Data and Reports, Vol. 10, July 1969*, pp. 289–296.

A 3-year study of the aquatic ecosystem around a nuclear fuels reprocessing plant, located in western New York State, has been conducted to find and evaluate natural indicators of environmental contamination. The study covered preoperational and early post-operational phases. The ecological vectors selected for study were algae, silt, and fish, all from Cattaraugus Creek and its tributaries. Samples were collected at several points upstream and downstream from the plant effluent and quantitatively analyzed by gamma-ray spectrometry. All vectors analyzed indicated process of uptake and concentration of ruthenium-rhodium-106, cesium-137, cesium-134, and/or zirconium-niobium-95, and sometimes cobalt-60.

In addition, the concept of using natural indicators not native to the streams under study was tested by translocating fresh water clams from Chautauqua Lake, 60-miles southwest of the site, and placing them in the streams around the plant. The clams not only thrived in their new environment but upon analysis showed definite interaction by concentration of the above radioisotopes with the shells showing approximately twice the radioactivity of the soft parts of the clams. This concept might prove to be a sensitive indicator of environmental contamination.

KEYWORDS: Algae, clams, fish, gamma-ray emitters, nuclear fuels reprocessing plant, radionuclides, silt, surveillance, water.

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July 1969

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